Winter Olympics Special: The Slippery Science of Ice Skating

By Michael Q. Bullerdick

Learning how to ice skate is a tricky bit of business that requires athleticism, a healthy sense of balance, and a high pain threshold. Of course, you also need a decent pair of skates and a pond-sized patch of slippery ice. Those last two items are easier to summon than the rest and they have been for a period going on 3,000 years now. But it might be surprising to note—especially during the Winter Olympics—that until just a few years ago, physicists didn't fully understand how skating worked. More precisely, they lacked a fundamental knowledge of what *exactly* makes ice slippery.

Sure, they knew that running a thin blade along smooth ice reduces friction in a way that accounts for a good deal of the gliding that makes skating fun. But that's not all of it. People slip and slide on ice without the benefit of ice skates and even while trying to stand still. Why?

Almost everyone will say that ice is slippery because it's—well—*wet*. Except that it isn't. Not in a purely scientific sense. Ice only feels wet due to the melting effect caused by your much warmer touch. At the freezing point, which any grade school child can tell you is 32 degrees, water crystalizes, meaning it goes completely solid. Yet despite that transformation, and the absence of a liquid lubrication, you can still slip and skate just as well. That fact becomes obvious at rinks where ice temperatures are kept at about 26 degrees, and in the context of subzero conditions, which any ice skater will tell you makes no difference beyond an upgrade in outerwear.

But if water isn't the thing that puts the "slip" in slippery, what is? In pondering that very question over a century ago, Michael Faraday—one of Albert Einstein's science heroes—wondered if it was possible for water (liquid) and ice (solid) to exist in a state halfway between each other beyond the freezing point. After pressing two ice cubes together and watching them fuse to form a single block, Faraday hypothesized that ice might perhaps contain an intrinsic "solid but liquid-like" invisible molecular layer, and that such a quasi-layer might even hold steady in subzero temperatures.

Following Faraday's lead, scientists began turning their attention to pressure and friction. The resulting theory, called the "pressure-melting effect," asserted that a skater's weight would exert intense pressure on the point where the blade contacted the ice. In turn, this pressure would generate just enough heat to melt a thin layer of ice for use as a lubricant. This process, the theory continued, would remain undetectable to the naked eye because the thin film of water would instantly refreeze with each glide step.

Not surprisingly given its plausibility, the pressure-melting effect is still routinely referenced as fact. But the theory simply doesn't hold water—literally or figuratively. For one thing, it fails to completely explain the important point about why people who wear wide-soled shoes still slide on ice even while attempting to stand still, although reduced friction plays a part. For another, there's the work of Robert M. Rosenburg. In his 2006 article in *Physics Today*, the emeritus professor of chemistry at Lawrence University proved that the average skater exerts a pressure of only 50 pounds per square inch, which results in a melting temperature of only .03 degrees at contact point. That's nowhere near a steep enough drop to melt ice.

As it turns out, the critical mystery lubricant is not water but—as Faraday had surmised—the ice itself. More specifically, it’s the tiny ice molecules that comprise the top layer of any frozen block. Although these molecules are bound to the ones below them within the larger mass, they are not as solidly compressed. As a result, they can readily fuse with new ice layers, as Faraday demonstrated with his ice cubes, and they are loose enough to get pushed free and roll around, making them as efficient a lubricant as water molecules.

As difficult as it is to believe, that critical point wasn’t proven until 1996, when Gabor A. Samorjai, a surface chemist at the Lawrence Berkeley National Laboratory, bombarded three thin ice layers with low energy electron diffraction, a technique used to determine crystalline structures. The procedure should have yielded similar scattering signatures for all three layers of ice molecules but Somorjai’s tests revealed only two. That’s because the molecules in the upper third layer, although solid, were behaving much like a liquid, vibrating at amplitudes three or four times faster than those in the lower layers. In short, Somorjai had confirmed the existence of Faraday’s intrinsic, “liquid-like” layer of ice. What’s more, he also confirmed, as Faraday had surmised, that such a layer was present even in subzero temperatures. Somorjai’s tests went as low as minus 235 degrees.

That’s far too drastic a temperature for ice-skaters to risk their lives testing but sporting goods manufacturers are currently using the lab findings to experiment with materials, finishing techniques, blade curvatures and edge cuts of their skates. And research development departments across various industries are doing the same, referencing the findings to improve stability, grip and the stopping power of tires and footwear that are set to hit the market in the coming years. Until that happens—or unless you’re an ice skater—it’s probably best to keep off the ice.