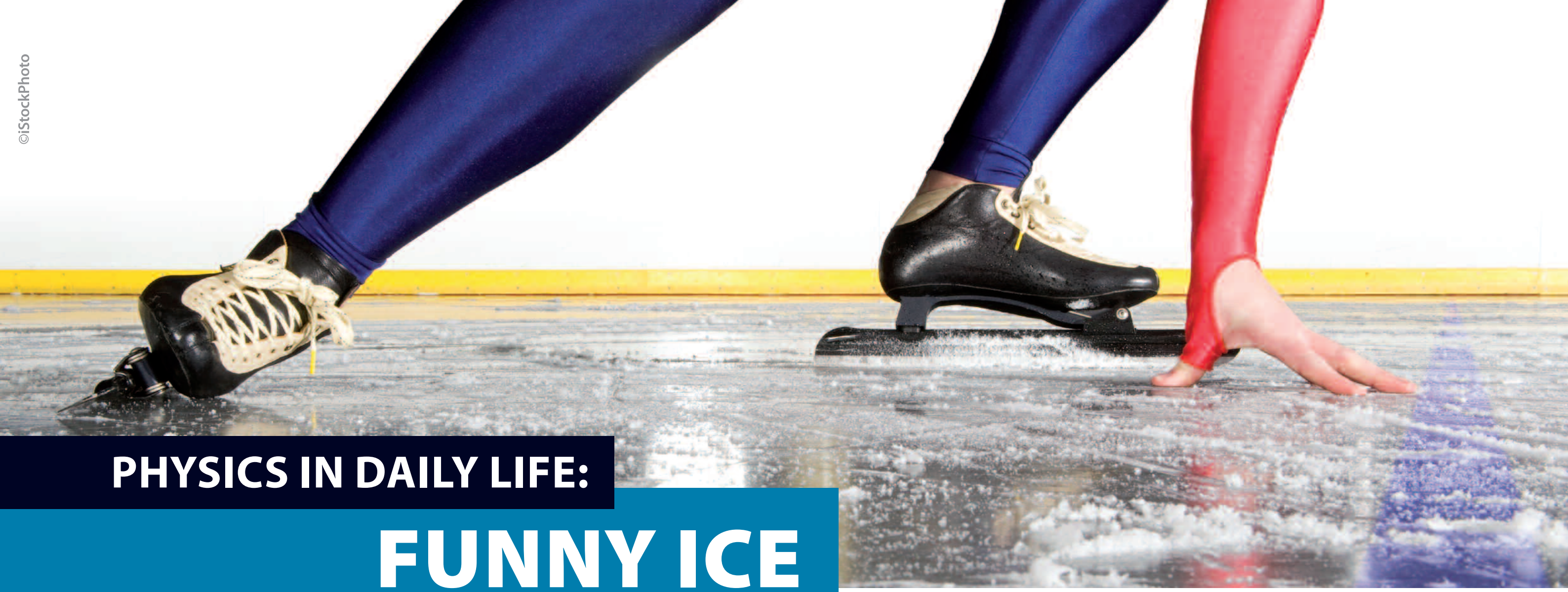

PHYSICS IN DAILY LIFE: FUNNY ICE

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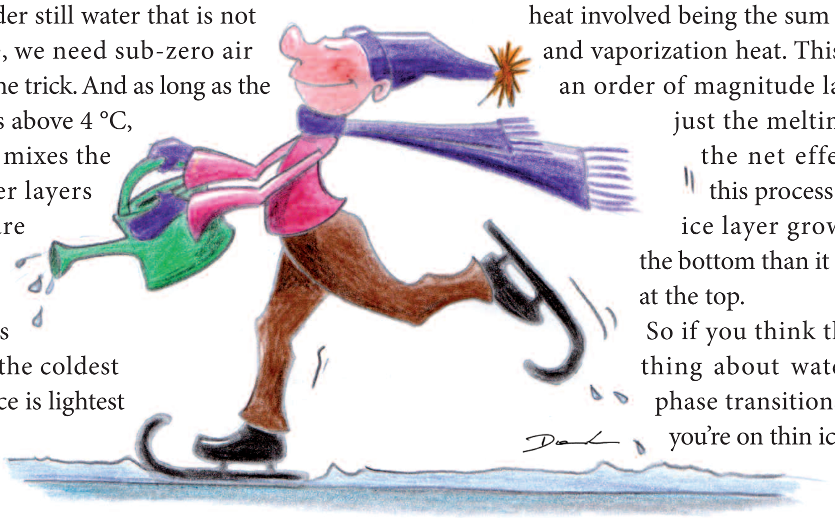
Water is a great substance, especially when it freezes. It becomes slippery and is fun to skate on. But why is it that ice is so slippery? It is not because it's flat. Glass, for example, is flat but not slippery. What we need is a layer of water to turn a flat surface into a slippery one. And sure enough, if we skate on ice we skate on a thin layer of water.

So where does the water come from? Many people think it's because of the pressure that the skater puts on the ice. After all, pressure lowers the melting point, and a skater's weight on a tiny skate makes quite a lot of pressure. But if you do the calculation this turns out to change the melting temperature by a few tenths of a degree at most. So this explanation is wrong. Hardly surprising, when you consider that a hockey puck with its negligible weight slides so well across the ice. In fact, we don't need pressure at all. There is always a thin layer of liquid water on the ice, up to some 70 nanometres thick if the temperature is just below freezing point. Basically this is because the molecules in the uppermost layer miss neighbours at one side, so they are not as tightly bound as the molecules in the bulk. Therefore ice is wet, and that allows us to glide so beautifully almost without any resistance.

So much for the skating fun. What about the freezing process, if we consider still water that is not flowing? Of course, we need sub-zero air temperatures to do the trick. And as long as the water temperature is above 4 °C, natural convection mixes the water, since warmer layers near the bottom are lighter and rise. But once the water is at 4 °C, it has reached its highest density, so the coldest water near the surface is lightest and remains on top.



Convection stops, and the freezing process can begin. This explains why shallow water freezes sooner than deep water.

If the air temperature rises again, is there something special about melting of the ice layer? For reasons of symmetry we may expect that the melting process is just as fast as the freezing, if the temperature differences are supposed to be equal and opposite.

Wrong. During freezing in still cold air, the air layer just above the ice is warmer than the rest of the air. Natural convection now helps to cool the ice. By contrast, if the ice is melting due to rising air temperature, the ice is relatively cold, so the cold air next to it will have no tendency to rise. Convection will *not* set in to increase heat transport. We conclude that melting is slower than freezing.

Skaters hate to see the ice disappear. Fortunately, as long as the air temperature remains sub-zero and if we can ignore radiation, the thickness of the ice layer should remain unchanged. Or does it? We realize that, even below 0°C, there is a finite vapour pressure, so water molecules will go directly from the solid to the gaseous phase, by sublimation. Many skaters will conclude that this is bad news, since it will decrease the thickness of the ice layer.

Wrong again. Sublimation cools the ice surface, the heat involved being the sum of melting and vaporization heat. This is almost an order of magnitude larger than just the melting heat, so the net effect is that this process makes the ice layer grow faster at the bottom than it disappears at the top.

So if you think that everything about water and its phase transitions is trivial, you're on thin ice… ■