Why pints spill but straws don't—researchers uncover the science of spilling

October 25 2016, by Hayley Dunning

Credit: Imperial College London

New research shows that it is not only the size, but the shape of a tube that determines whether a liquid will spill out of it when tipped over.

Glasses of liquid, when turned horizontally, inevitably spill. This is not necessarily the case however with very thin straws, which, when turned on their sides, can retain liquid in them.

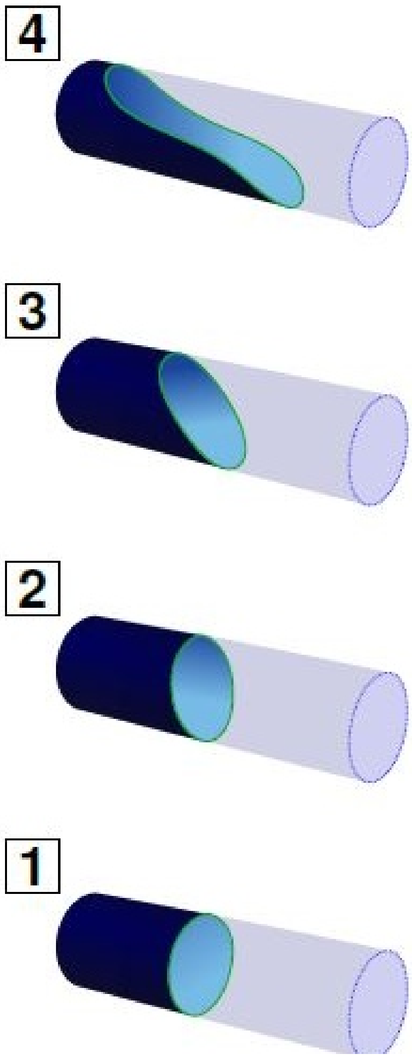
This simple relationship was thought to be based purely on the size of the tube opening, but by investigating more closely, a team of researchers have determined that this rule of thumb doesn't always hold true.

The shape of the tube turns out to be important too, and if it is squashed enough – forming an elliptical shape – then no matter how thin the straw is the liquid will always spill out.

This new understanding has practical applications in technologies that have liquids present on small scales - such as biomedical diagnostics, oil recovery and inkjet printing - where choosing the right tube shape could be as important as its size.

The calculations – which took over seven years – were carried out by Professor Andrew Parry of Imperial College London, Dr Carlos Rascón of the University Carlos III de Madrid, and Professor Dirk Aarts of the University of Oxford. Their results are published today in *Proceedings of the National Academy of Sciences*.

Co-author Professor Parry, from the Department of Mathematics at Imperial, said: "If your pint glass falls over, tragedy has struck and you know you're going to spill your beer. But conversely that doesn't necessarily happen if you suck your beer into a straw and turn that horizontally. In that case common experience tells us that if the straw is thin enough the liquid stays in. Now, we have discovered that it should be possible to create minute straw shapes that would mean that any liquid spills, or empties out of the tube, no matter how thin it is."



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Surface tension

The team's findings are based on the behaviour of liquids in contact with surfaces. If you look closely at water in a glass, you can see the edges curve up slightly, so that the surface of the water looks like a shallow bowl.

This is due to the force of surface tension, a phenomenon that determines how the liquid surface touches the sides of the glass. The majority of the liquid in the glass is not held this way, so that when the glass is tipped to the side, the force of gravity wins and all the liquid spills out.

On the other hand, if the diameter of the glass is small enough, such as in a very thin straw, then gravity is not able to overcome the forces of surface tension and the liquid remains within the tube. This is why drinking straws, or capillaries in pens, are only a few millimetres across.

However, the researchers found that this simple rule breaks down when the shape of the tube is changed from being circular to being elliptical or triangular cross-section. In this case it is possible that the liquid will spill even when the tube is microscopically small.

Their precise calculations could have application in devices that use liquids designed to be sensitive to very small changes in environment, for example temperature. If the size and shape of the tube are carefully designed, then the area of the exposed liquid surface could change dramatically in response to small changes as it crosses the threshold from staying put to spilling out.

The power of surface tension to draw liquids up very narrow vertical tubes has been extensively studied but how it works when the tube is tilted to the horizontal, where the geometry of the tube is an extra key ingredient, has received much less attention.

More information: Carlos Rascón et al. Geometry-induced capillary emptying, *Proceedings of the National Academy of Sciences* (2016). DOI: 10.1073/pnas.1606217113

Provided by Imperial College London

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