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Kitchen capers—the answer

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Abstract
A selection of challenging questions with experiments that can be performed in the kitchen, covering centre of mass, pressure and sound. The answers the questions in *Phys. Educ.* **55** 037002.

1. Titling bottles

Three identical bottles are placed on a rough surface such that slipping is unlikely when the bench is titled (figure 1). One bottle is empty, one is half filled and the third is full. As the angle of tilt of the surface is increased the bottles fall over in order. What happens is very dependent on the bottles themselves. A glass bottle can have a relatively high centre of mass. Whether a bottle tips depends on both the position of the centre of mass of the bottle and the size of the base. In the example given the highest centre of mass is in fact the empty bottle, so this bottle falls first, followed by the full bottle and lastly the half full.

The examples lend themselves to further investigation with bottles of different materials and shapes. Pupils can be challenged to predict which of any number of bottles will fall first, which is not easy especially if the bases are of different size (figures 2 and 3). A plastic bottle has much less mass compared with any liquid within it and this will affect the toppling positions. Students may be asked how the lid will affect toppling. It is fairly obvious that other everyday objects may be introduced.

The bottle on the left is the last to fall largely because of its larger base.

Interesting discussions can be initiated using similar objects, for example the cans shown in figure 4. The tall can topples first but what about the two others which have proportionately similar dimensions.

2. Marshmallows under pressure

Some marshmallow sweets are placed in a 'coffee saver' (figure 5) from which air can be withdrawn to reduce the pressure. Reducing the pressure is apparently a way to increase the shelf life of coffee stored.

When the pressure in the chamber is reduced the air trapped in the sweets expands which greatly enlarge the sweets (figure 6). If a sealed packet of marshmallows is placed in the container the bag itself expands (as happens with a crisp packet in an airplane when the cabin pressure reduces after takeoff) however the marshmallows inside the packet remain small (until the packet bursts!!)

A similar experiment can be performed using a partially blown up balloon in the container. When the pressure is reduced the balloon appears to inflate. Of course, no extra air can get into the balloon, the balloon inflates because of the difference in pressure between the inside and outside (figures 7 and 8).

3. In the soup

The soup is stirred so that it rotates around the pan. When you stop stirring some soups (cream of tomato shows this particularly well, figure 9), the soup gradually comes to rest then reverses its direction. It as if the soup slightly overshoots its equilibrium position and then returns to it.

This is due to the adhesive forces between the pan and the soup. Even when being rotated the

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Figure 1. Bottles on bench before titling.

Figure 2. Showing three different bottes, which will fall first?

outermost layer of soup, in contact with the pan edge remains stationary, just like the water at the bottom of a fast-flowing river. This ‘at rest’ layer is cohesively attracting the inner layers of soup which continue rotating whilst slowing down and are in that last moment pulled backwards before finally coming to rest. The size of this cohesive force within the soup is critical. If it is larger (as in some other soups) the soup simply comes to rest as might have been expected. This gives an opportunity for further investigation.

Forces between fluids and solid surfaces were explored by Henri Coanda in the last century. Coanda was a Romanian physicist whose

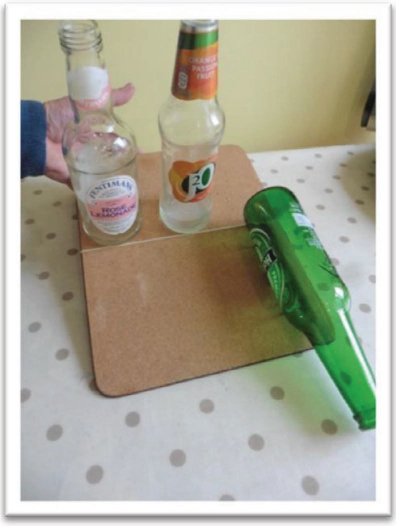

Figure 3. Showing the board being tilted (an elastic band across the board prevents slipping).

Figure 4. Drinks cans on tilting board. Which will fall over last?

work on aerodynamics led to applications in flight. The International Airport in Romania at Bucharest is one of the few airports named after a scientist *Aeroportul Internaţional Henri Coandă*.

The Coanda Effect is the tendency of a fluid to cling to any surface it moves over. There are many applications around us every day, although as this effect is rarely on a school syllabus, these effects often go noticed but without their explanation, from dribbling babies to flying aeroplanes.

Figure 5. Marshmallows at atmospheric pressure.

Figure 6. Marshmallows after pressure is reduced.

4. Mystery mug of chocolate[1]

Some instant hot chocolate powder was added to a mug of hot water and mixed thoroughly quickly. The bottom of the mug was struck gently with the spoon again and again and the frequency of the note heard noted together with any subsequent changes.

[1] Thanks to Jean-Brice Meyer of Science on Stage France for this idea. Details from LP2I—Lycée Pilote Innovant International.

Figure 7. Balloon before and after pressure outside is reduced.

Figure 8. Balloon before and after pressure outside is reduced.

Figure 9. Stirring the soup.

As the mug is tapped with the spoon, the pitch of the note heard gradually increases to a steady value.(www.dailymotion.com/video/x5ap0g6_les-mysteres-de-la-tasse-phenomene-etudie_school)
The explanation is complex but linked with the disappearance of bubbles in the liquid with time. This is linked to the 'Allasonic effect'. It is all to do with the bubbles (their compressibility and density), and can be deduced (approximately) by the Newton Laplace equation. The presence of the bubbles changes the velocity of the transmitted waves in the liquid.

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David Featonby retired from school physics teaching at a Newcastle comprehensive school in 2003, where he worked as head of physics, head of science, head of sixth form and assistant head (though not all at the same time). Most recently he has been an active member of the Science on Stage Europe executive board, helping to arrange its biannual festival and supporting on going cooperation between teachers. He continues to participate in many conferences across Europe with a variety of workshops, including 'What happens next?' based on this column.