UNITED SCIENTIFIC SUPPLIES, INC.

OPERATING INSTRUCTIONS AND ACTIVITY GUIDE

# THE SPILLNOT™

**SPNT01**

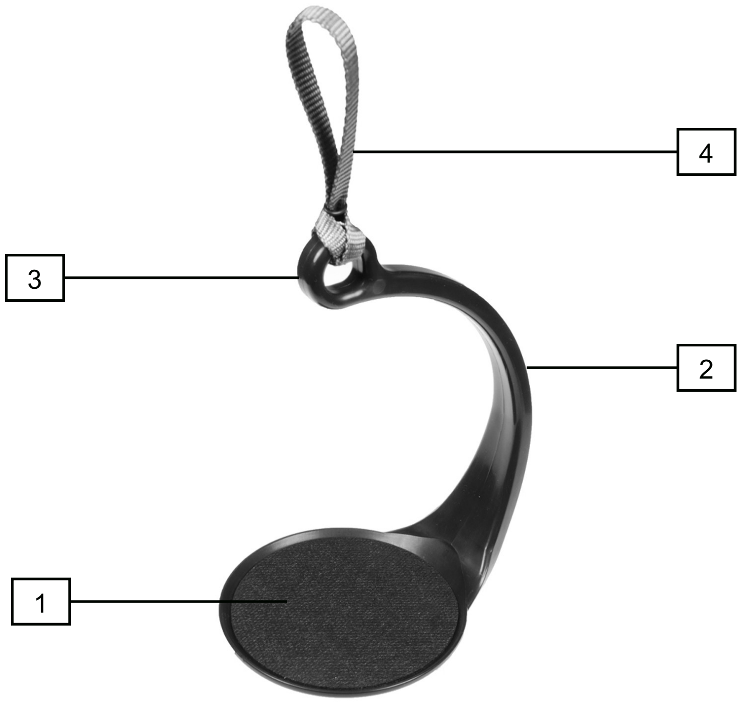


*Figure 1*

## DESCRIPTION

The SpillNot™ is a simple but effective device for transporting an open container of liquid without spilling. It also presents an opportunity for examining some surprising aspects of the physics of accelerations in liquids.

The SpillNot™ consists of a molded tray with a coaster (1, *Figure 1*) attached to a rigid support (2) that curves around the outside of the tray to an eye (3) directly above the center of the tray. A flexible webbing handle (4) is looped through the eye.

The SpillNot™ is 19.5 cm high, excluding the 8 cm long handle, and the diameter of the tray is 11.2 cm. The height clearance for the liquid container is 14 cm (full tray width.) The empty weight is 138g.

A container (usually a beaker or a glass) full of liquid is placed centrally on the coaster, and the SpillNot™ is carried by the flexible handle. The shape of the SpillNot™ and the flexibility of the handle combine to sharply reduce the sudden accelerating forces applied to the liquid, and this prevents spillage in most situations.

**INSTRUCTION MANUAL**

**To Spill or to SpillNot? That is the question…**

THE MOLECULES of a liquid are held together by forces of cohesion, so a mass of liquid has a definite volume. But the molecules are free to move around each other, so the liquid does not have a definite shape.
If a force is applied to the liquid (always gravity, and sometimes other forces too) the liquid molecules will move until stopped by a solid—such as the wall of a glass. So the liquid at rest will take on the shape of its container. If the liquid doesn't fill the container completely, the top surface of the liquid will be exactly horizontal.

What happens if a container of liquid is pushed sideways by a force F—for instance, by a hand?

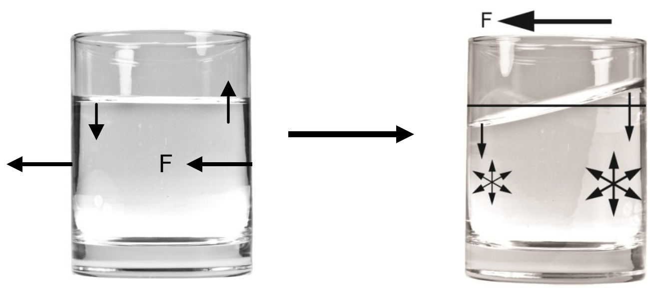


*Figure 2a* *Figure 2b*

*Figure 2a* shows a glass of water at rest suddenly pushed by a force F. The glass is a rigid solid, so the front and back of the glass both begin to move in the direction of F at the same rate. The liquid layers next to the glass walls begin to move with the walls, but are resisted by the layers next to them. They conform to the shape of the glass, but the only direction they can adjust is up or down, so the front layers move down to prevent a gap forming as the wall moves away. At the back, the wall is moving towards the liquid, so the first liquid layer is forced up. As the force is transmitted from layer to layer in the liquid, this creates the tilted surface shown in *Figure 2b*.

How does this up-and-down movement translate into a sideways movement of the liquid? At each level in the liquid, the pressure is proportional to the depth of liquid, and acts equally in all directions (Pascal's Law). For the back layers of liquid, the depth has become greater, increasing the pressure at every level. At the front, the depth has become less, reducing the pressure at every level. So now there is a pressure gradient in the liquid from back to front, and every part of the liquid experiences a force towards the front, causing it to accelerate along with the glass.

It is clear that the larger the force F, the larger the force on the liquid must be to produce the same acceleration as the glass. This means that a steeper tilt of the surface is needed for equilibrium. At some point, the tilt is steep enough for the top layer of liquid to rise over the edge of the back of the glass and spill out.

Also, if a smoothly moving glass of liquid is stopped by a backward force, the same situation is encountered in reverse, with the liquid spilling over the front of the glass if the stopping force is large enough.

The key to not spilling the liquid when moving an open container is clearly to keep the lateral forces applied small enough to prevent the surface tilt from becoming too steep.

The design of the SpillNot™ reduces the steepness of the acceleration tilt when a force is applied via the handle, and prevents spillage.

**The SpillNot™**

The SpillNot™ consists of a tray and coaster with a rigid support pillar and a flexible webbing handle attached to an eye on the pillar (*Figure 3*):

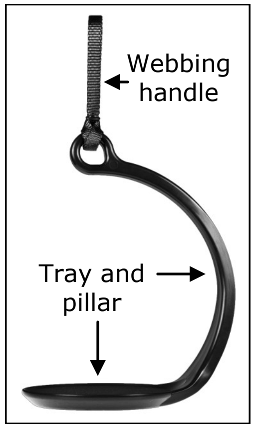


*Figure 3*

Since the tray and pillar form one rigid piece, forces applied to either part will be transmitted to the other part. However, the webbing handle is flexible (like a rather stiff thread) and can slide on the eye, so forces applied to the handle will only be transmitted to the pillar at the same magnitude if they act along the length of the handle. Lateral forces applied to the end of the webbing cause the webbing to bend and are only transmitted weakly or not at all to the pillar.

**So how does it work?**

When a container of liquid is placed on the tray, the center of mass of the SpillNot™ plus container is moved to low down on the combined object, because the mass of the container of liquid is several times larger than the mass of the SpillNot™ alone (*Figure 4*):

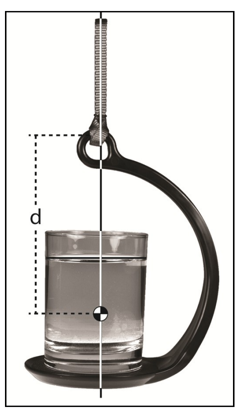


*Figure 4*

If the SpillNot™ is lifted straight up by the handle, it will hang with the center of mass vertically below the point of suspension. The tension in the handle webbing is equal to the combined weight of the SpillNot™ and container of liquid, W.

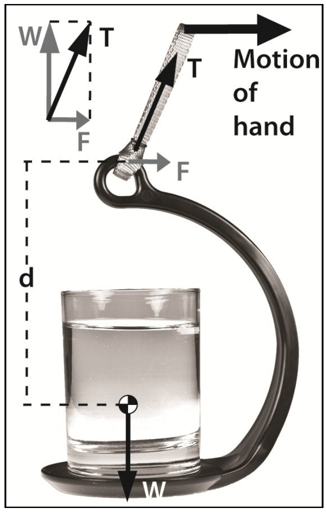


*Figure 5*

When the handle is moved sideways to transport the container of liquid, the webbing material bends and/or slides on the eye, and the tension changes to a value T. The insert in *Figure 5* shows that T is composed of a vertical component W that supports the weight of the object and a horizontal component F that moves it in the direction of transportation.

But the component F has another effect as well as to move the whole rigid unit sideways. Through the connection of the webbing to the eye, the force F is applied to the top of the SpillNot™'s pillar, which is a distance d above the center of mass, where the weight acts. This applies a clockwise torque F x d to the SpillNot™, which rotates until the center of mass is once more in line with the tension force in the webbing.

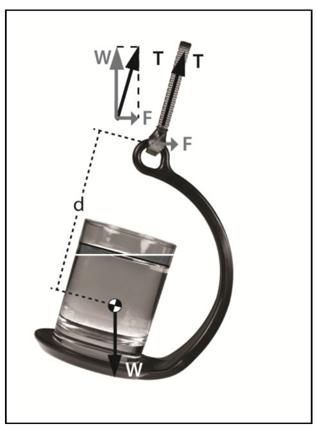


*Figure 6*

*Figure 6* shows the new situation. The horizontal force has once more caused the liquid to "pile up" at the back of the container, as we discussed before. But now there is an important difference. The "pile up" occurs *with respect to the horizontal*, but the container