Letters
to the Editor

Inverse Lawn Sprinkler

Paul Hewitt's encouragement to build an inverse lawn sprinkler[1] out of a soda pop can motivated me to make some simple modifications to his design so that I could more fully explore its rotational dynamics. Rather than poking holes with a nail, I drilled holes in the side of a can and inserted ribbed drinking straws, of the sort that can be bent into various shapes. I sealed the straws to the side of the can with modeling clay, so that I could move the straws in and out radially to vary the moment arm of the torque delivered by the water as it strikes the bends in the straws. Also, instead of suspending the can from strings, I taped the can to a low-friction pulley spinning freely at the end of a short rod that I could grasp in my hand. In this way, no ballast is needed (which adds unwanted extra mass) to hold the empty can partly submerged in a sink full of water when running the sprinkler in reverse flow. Side- and top-view photographs of the can are shown in Figs. 1(a) and (b), respectively.

I experimented with three bend geometries of the straws, illustrated in top view in Fig. 2: (A) U-shaped straws, (B) S-shaped straws, and (C) L-shaped straws. In all three cases, when the can is filled with water and held by the rod in air above the sink, the can rotates in the counterclockwise direction, as one would expect in reaction to the clockwise tangential water jets issuing outside the can. Now suppose we empty the can of water and submerge it in a full sink to just below the brim of the can, so that water flows into rather than out of the can through the straws. Which way will the can rotate for each of the three illustrated geometries?

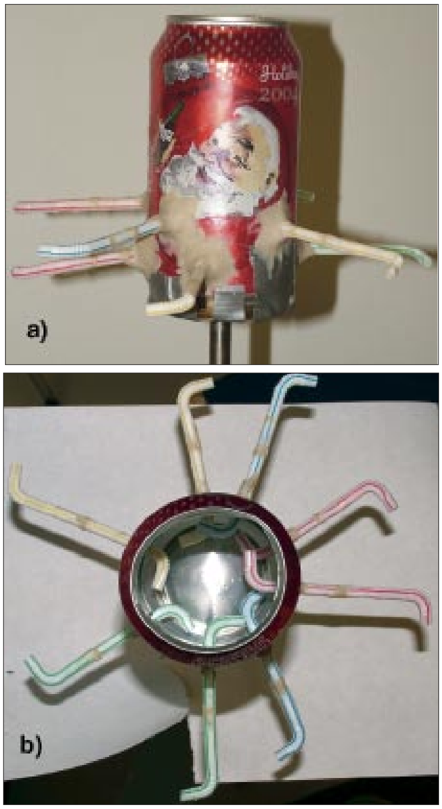

Fig. 1. (a) Side view of the can. Since the straws were fairly narrow in diameter, I used eight of them to increase the flow rate. The straws are near the bottom of the can, to increase the hydrostatic pressure differential between the inside and outside of the can. (b) Top view of the can in geometry B.

Experimentally, it is found that can A rotates counterclockwise, can B rotates clockwise, and can C has negligible rotation. (It is hard to avoid slightly jiggling the can as it is immersed in the sink, so I cannot definitively rule out a small amount of rotation in case C.) The observed rotational rate in cases A and B is consistently reproducible; however, it is small and transient. I suspect there are two reasons for the small size of the angular speed: the can experiences significantly greater drag as it rotates in a sink full of water than it does in air in forward flow; and the water entering the can is swirling around and viscously brushing against its inner edge, in contrast to forward flow where the water streams into the sink without hitting the can. The transient nature of the effect is due to the fact that the can quickly fills up with water. (In contrast, in forward flow the can is emptying out and reducing its moment of inertia. Its final deceleration is therefore only due to the frictional torque in the bearings and air drag on the straws.) One could use an aquarium pump to keep the can empty and so create a true Feynman inverse sprinkler, but this defeats the simplicity of the setup. If the straws are pushed inward through the holes in the can until the inner bends in geometries A and B are stacked up along the axis of the can, then the inner spouts point radially outward. In this case, the water issuing from these straws inside the can carries no angular momentum relative to the axis of the can. This is also true of geometry C, and sure enough cans A and B now exhibit negligible rotation.

Geometry B corresponds to Hewitt's arrangement and the observed direction of rotation agrees with his results and explanation.[1] On the other hand, configuration C is the classic Feynman sprinkler

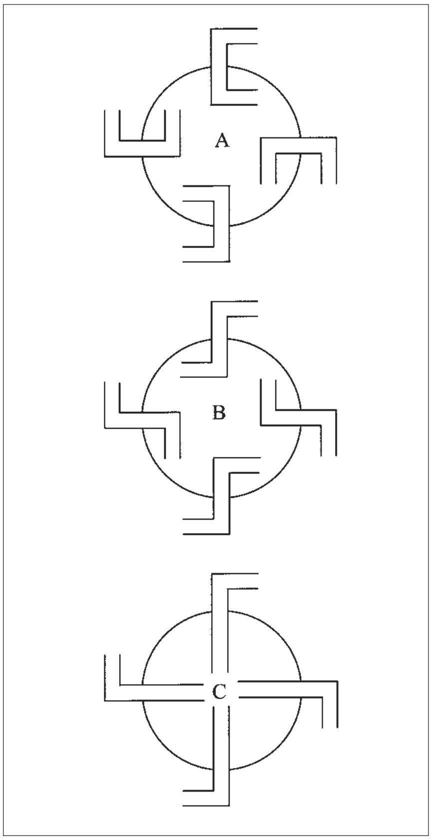

Fig. 2. Three geometries of the straws as seen from above. For simplicity, only four straws are shown.

geometry. Its lack of rotation in steady reverse flow results from a balance between the competing effects of the net water pressure on and momentum transfer to the elbows in the straws.[2] When the analysis in Ref. 2 is extended to all three of the geometries investigated here, it correctly predicts the observed results. Instructors are encouraged to reproduce Fig. 2 on a transparency and ask their classes to predict the directions of rotation of the sprinkler in both forward and reverse flows.

References

1. "Figuring Physics: Inverse Lawn Sprinkler," *Phys. Teach.* **42**, 548 (Dec. 2004).
2. A. Jenkins, "An elementary treatment of the reverse sprinkler," *Am. J. Phys.* **72**, 1276–1282 (Oct. 2004). Also see the supporting follow-on Letter to the Editor by E. Creutz in *Am. J. Phys.* **73**, 198–199 (March 2005).

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