FREE-FALL BOTTLES & TUBES

Free Fall Bottles

Drill a hole (about 1/4" - the exact diameter is not critical) in the bottom of a plastic water or soda bottle (you can use any size, from 0.5 liter to 2 liter, depending on how visible you need to make the demonstration). Put your finger over the hole, and fill the bottle with water until it is about half full. Climb on a table or ladder so you can hold the bottle as high as possible off the floor -- you can probably make do by just holding the bottle as high off the ground as you can reach, but the ladder or table makes things more visible and dramatic. Have a large plastic tub on the floor directly below the bottle. Take your finger off the hole, and let water fall into the tub. Then drop the bottle, with the water still flowing. As the bottle falls, note that the water stops flowing.

Repeat the process using a bottle with a hole in the side rather than the bottom (or two holes in the side that are opposite each other if you really want to get things wet!).

NOTE: Even with the tub, both these demonstrations will probably get the floor wet, and the one with two holes is particularly sloppy. Have a mop and/or some towels available! If the floor is susceptible to being damaged by water, consider doing the demonstration outside.

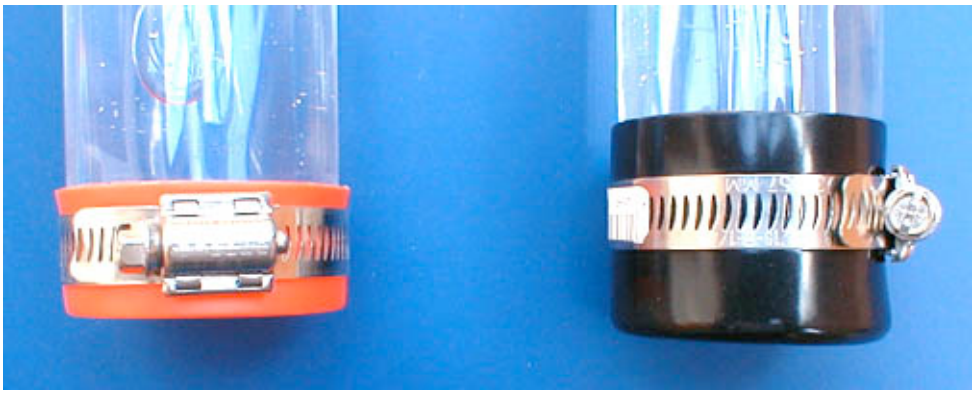
Physics tells us that, ignoring air resistance, all objects fall with the same acceleration. When the bottle is held with the hole(s) uncovered, the water falls as expected. When the bottle itself is released, the bottle and the water fall together, and no water flows from the bottle. This makes the water seem "weightless" during the free fall. A rider on a free-fall ride such as the Drop Zone feels "weightless" during the free-fall portion of the ride. Just as the water does not press against the bottle during free-fall, since both are falling together, so the rider does not press against the seat during free-fall, and thus feels "weightless."

Free Fall Tubes

Obtain a plastic tube with tight-fitting caps for both ends (TAP Plastic in the Bay Area sells a 2-ft tube with rigid orange plastic end caps for around $5.00. There are also flexible black plastic end caps available for a small extra amount if these are more to your liking. Put a cap on one end of the tube and secure it with a hose clamp or duct tape (you can also use epoxy cement, but you won't be able to remove the cap thereafter). If you use a hose clamp, tighten it enough to keep the cap on and provide a watertight seal, but not so tightly that you break the tube. Fill the tube with water to the very top, and float a ping-pong ball (preferably a colored one for easier visibility) on the water surface.

Put the second cap on as far as it will go, so that the ping-pong ball is pushed under water. As you do this, the air bubble inside the cap, and the water displaced by the ball, will be forced out of the tube. Secure the cap with a hose clamp or duct tape and/or epoxy.

Free-fall tube



Close-up view of hose clamps and two different end caps.

(continued)

Hold the tube vertically, so that the ping-pong ball is floating at the top of the tube. Rapidly turn the tube upside down so that the ping-pong ball is at the bottom. Notice that it immediately floats up the length of the tube to the top. Invert the tube, and when the ball has floated about 1/3 of the way up the tube, toss the tube straight up in the air about a foot, and catch it on its way back down. Notice that while the tube is in the air, the ball stays at the same place in the tube and stops floating to the top.

Climb a ladder or get on the top of a strong table so that you can hold the tube several feet off the ground. Have another person kneel at the foot of the ladder or table to act as a "catcher" when you drop the tube. Invert the tube, and when the ball has floated about 1/3 of the way up the tube, drop it and have the other person catch it. As the tube drops, notice that the ping-pong ball again stays at the same place in the tube, and stops floating to the top. **IMPORTANT! DON'T LET THE TUBE HIT THE GROUND! It may break if it does. It might be a good idea to practice with a few short drops first, and gradually go to higher drops. If the floor is susceptible to water damage, it might be a good idea to do the demonstration outside, or put a tub of some sort on the floor under the drop zone until you are confident enough with the process.**

Now try throwing the tube to another person. Just before throwing it, invert the tube so that the ping-pong ball starts floating upward. When the ball is about 1/3 of the way up the tube, **keep the tube in a vertical orientation** and toss it so that it travels in an arc toward the other person (the path of the tube will actually be a parabola). It may be easier to throw the tube if you put one hand under the bottom while throwing it. Observe the behavior of the ping-pong ball as the tube travels on its path to the catcher. Notice that again the ball remains at the same place in the tube and stops floating to the top. **IMPORTANT! ONCE AGAIN, DON'T LET THE TUBE HIT THE GROUND! It might be a good idea to practice with a few short throws first, and then gradually go to longer distances.**

When the tube is held normally, the ping-pong ball floats to the surface, since it is less dense than the water around it. But when the tube is dropped or thrown it is in free-fall. Free-fall exists when the only force acting on an object is gravity. This situation obviously exists -- ignoring the negligible air resistance -- when the tube is dropped, but it also exists when the tube is thrown in an arc, since once the tube leaves the thrower's hand, gravity is the only force acting on it, even though it is travelling forward at the same time that it is travelling up and down. All objects in free-fall together have the same acceleration, and travel with the same speed; therefore the ping-pong ball travels right along with the water surrounding it, and no longer rises in the tube.

NOTE: This whole demonstration can also be done with just a large air bubble in the tube rather than a ping-pong ball. In fact, you may find it worth making two separate tubes, since it is also interesting to see the water flow pattern around the air bubble as the bubble rises in the tube.