Circular Motion Paradox

Physical Science Demonstration

Introduction

You accelerate around a sharp curve and you feel like you are being thrown toward the outside of the car. Are you being thrown into the car or is the car accelerating into you? What would happen to a helium-filled balloon floating inside the car when the car accelerates around the corner? Which way would it move?

Concepts

- Uniform circular motion
- Centripetal force
- Center of curvature

Materials

Circular Motion Paradox Apparatus

Water

Safety Precautions

This demonstration is considered safe. Follow all normal laboratory safety rules.

Preparation

The jars on the apparatus will need to be filled with water so that the buoys (fishing bobbers) are submerged beneath the water in each jar and floating freely above their tether line. See Figure 1.

Adjust the bobber along the length of the tether line to assure that the buoys are submerged. The entire apparatus will need to be inverted while the jar lids are being tightened in place on the rotating platform. Be sure to hold the lids and tighten the lids until there are no leaks.

Turn the axle into the threaded base and use the locknut to lock the axle in place. The tension on the axle at the rotation spot can be adjusted by raising and lowering the collar below the rotating platform. An Allen wrench is needed to loosen the set screw. Wax or silicon spray can be used to create less friction of the rotating platform on the shaft.

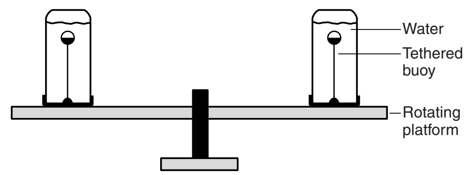

Figure 1. Water-filled jars with buoys

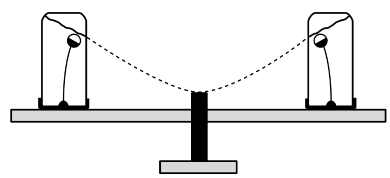

Figure 2. Position of water and buoys while spinning

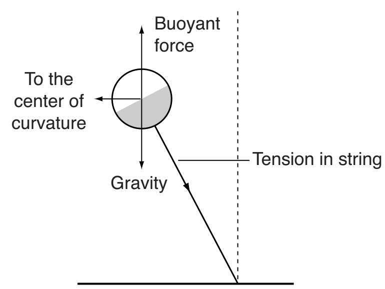

Figure 3. Forces acting upon submerged buoy.

Procedure

1. Explain the apparatus setup and allow time for discussion before actually performing the demonstration. Ask students to predict the movement of the buoys when the platform is spun and explain their predictions in detail and relate their predictions to real-life experiences.
2. To see the somewhat unpredicted results (buoys will actually move in toward the center of the circle—not outward), the apparatus needs to be spun. This can be done easily by hand and need *not* be with great gusto. As soon as the apparatus is spun and while it is slowing down, the inward movement of the buoys will be very obvious. The parabolic movement of the water outward will also be very obvious.
3. Repeat the spinning process several times until everyone sees the results clearly. Discuss the results.

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Disposal

With proper care, the apparatus can be used indefinitely. Empty the water from the jars when the apparatus will not be used for long periods of time.

Tips

- The effect is equally dramatic even if the jars are completely filled with water.
- An economy Circular Motion Paradox device can be made using a plastic lazy Susan, two 600-mL beakers, two bobbers, string, tape and water. Tie string to each bobber so that the string length is about ¾ the height of the beaker. Then, tape the loose end of one string to the inside bottom center of one of the beakers so that the bobber will float at the half-way point in the beaker when it's filled with water. Repeat for the other bobber and beaker. Fill each beaker about ¾-full with water. The bobbers should float at the half-way point inside the beakers and be completely submerged. Place the beakers on the lazy Susan 180° apart. Turn the lazy Susan slowly so the water does not spill out of the beakers and observe the paradox.

Discussion

The explanation for the observed behavior of the buoyed objects in the demonstration is as follows. The circular motion requires a net force directed toward the center of curvature. Since the tension exerted by the thread is directed outward, the force responsible for the circular motion can be exerted only by the fluid in which the buoy is immersed.

The water contained inside the jar is not at rest in the inertial frame of reference, but rotates together with the jar. Since the water is fluid, not rigid, and has a higher density than air, it is "thrown" to the outside of the turning jar because of its inertia (sometimes this is called the centrifugal force, which is a misnomer because there is no force that actually "throws" it outward). This rotation causes more water to flow to the outside and therefore the water pressure increases with distance from the rotation axis. Consequently, the force exerted on the liquid near the outer part of the jar is greater than the force acting on the fluid that is closer to the rotation axis. The net buoyancy force acting on the bobber is therefore directed toward the center of curvature which causes the buoy to move inward toward the center of curvature. This is similar to the principle of a centrifuge. The heavier, more-dense material is pulled to the bottom, and the lighter, less-dense material moves to the top.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, motions and forces

Circular Motion Paradox is available as a physical science demonstration kit from Flinn Scientific, Inc.

Catalog No.	Description
AP6382	Circular Motion Paradox—Physical Science Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.