Microgravity demonstration

Background Information

Earth-orbiting spacecraft experience a condition known as weightlessness. The astronauts and everything inside the spacecraft appear to float as if there was no gravity in space. But in fact the opposite is true. Gravity is everywhere and is especially important across the vast distances of space. It is gravity that keeps the Moon in orbit around the Earth, and the planets in orbit about the Sun.

While the astronauts may appear to have escaped gravity, they are really in a state of free-fall. We can imagine a similar sensation here on Earth as follows. Say you climbed to the top of an extremely high diving tower. You jump off the edge of the platform and begin to fall - that's gravity at work. But if you think about it, falling is really very similar to floating. Depending on your diving skills you might even be able to do somersaults mid-air, just like an astronaut in space. The difference is that your fall will end with a splash when you hit the water, while an astronaut can savour the experience because they never reach 'the bottom'. The astronaut will continue to fall for as long as they orbit the Earth.

So how does it work? The International Space Station (ISS) orbits the Earth every 90 minutes at an average distance of 400km. At this distance the force of gravity is only 10% less than what we feel on Earth. So the ISS and its crew are constantly being pulled back down to Earth. But, the Station is also moving forward at over 28,000 km/hour. The ISS wants to travel in a straight line, but gravity is pulling it back to Earth. This causes the path of the ISS to curve, and at that height and speed, the curved path of the ISS exactly matches the curvature of the Earth.

The condition of weightlessness or free-fall is sometimes called zero gravity but is more accurately known as microgravity. To truly escape Earth's gravity we would have to be over 6 million kilometres away from Earth, that's 17 times further away than the Moon. But it is possible to experience microgravity on Earth for short periods of time. Some amusement park rides, like tall roller coasters or vertical drops, achieve a couple of seconds of weightlessness – it's that feeling of leaving your seat for a moment.

These days, NASA achieves weightlessness using a military version of a Boeing 747, nicknamed the 'Weightless Wonder', though some still call it the 'Vomit Comet'. Once in the air, the plane shoots up into the sky. The plane's acceleration is so strong that the passengers become really heavy – gravity is almost double that on Earth. After a 30 second climb the plane changes direction, plunging back to Earth with an acceleration that matches Earth's gravity. For 20 seconds the passengers are in microgravity. In a 2 hour flight, over 40 stints of microgravity are performed.

Experiments performed in microgravity are being used to understand the role of gravity in many physical processes, such as materials science, power, propulsion, combustion, fluid physics and plasma physics.

This activity demonstrates free-fall. It is best done as a demonstration with students asked to predict what will happen when the cup is dropped before it is demonstrated.

Optional
If you have access to a video camera, record the falling cup closely, then play it back in slow motion.

What You Need

- Styrofoam or paper cup
- Pencil or other pointed object
- Water
- Bucket or other catch basin

What to do

1. Punch a small hole in the side of the cup near the bottom.
2. Hold your thumb over the hole and fill the cup with water.
   Ask the students what they think will happen if you remove your thumb. Why?
3. Remove your thumb and let the water pour out from the hole and into a catch basin on the floor.
4. Seal the hole with your thumb and refill the cup.
   Ask the students if the water will pour out of the hole if you drop the cup.
5. Have the students watch carefully as you drop the cup into the catch basin. The demonstration is more effective if you drop it from a great height – stand on a bench or table and hold the cup high up before you drop it.

Questions

1. What was different in the two demonstrations?
   In the second demonstration the cup and the water are in free-fall together.

2. Why didn't (as much) water flow out of the hole during free-fall?
   In free-fall, the water accelerates downwards at the same rate as the cup. The two were falling together hence no water fell out. The small environment of the cup and water experienced momentary microgravity.