Weightlessness in Orbit

Take-home message: We feel “weightlessness” when we are falling; when astronauts appear to be floating in space, they are actually falling with (i.e. at the same rate as) the space shuttle/station.

Key points:

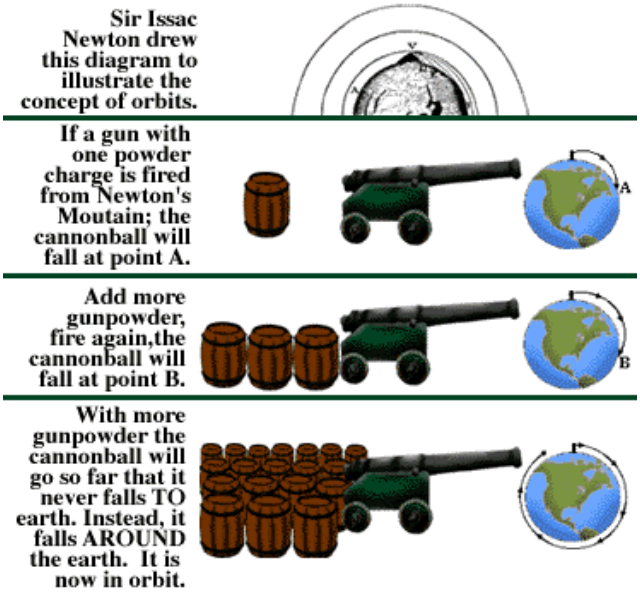
- When something is in orbit, it makes a circular (or elliptical/oval) path because earth’s gravity is pulling it. -- Another way of saying this is that things in orbit are “falling” toward the earth
- Astronauts seem to float in a space shuttle because they are falling at the same speed as the space shuttle

Materials:

- Set of photos, 1 per group
- Student worksheet, 1 per student
- Pencil, 1 per student + 1 for tutor
- Short (~ 8 in) length of thread, 1 per group
- Sheet of (normal) paper, 1 per group
- Marker
- 2-liter plastic bottle
- Construction paper (not white)
- 50 cm of thin string or thread
- Astronaut cut-out
- Scissors
- Ruler

Background (for tutor, don’t worry about reading through this during the lesson):
This lesson will focus on the idea that when astronauts are in space, they feel weightlessness because they are “falling” at the same rate as the space shuttle. To help explain how the space shuttle is “falling,” we will have to explain that gravity (the force that causes things to fall on earth, also) causes things to orbit in space. The main difference between falling into the earth and orbiting the earth is the initial speed of the object.

- From wikipedia: an orbit is the gravitationally curved path of an object around a point in space, for example the orbit of a planet around the center of a star system, such as the solar system.
- Weightlessness, or an absence of 'weight', is in fact an absence of stress and strain resulting from externally applied forces, typically contact forces from floors, seats, beds, scales, and the like.
- “Weightlessness” or “microgravity” refers to the feeling of being weightless. But there is always gravity! In fact, what we see as “weightlessness” is actually a free fall environment.



Common misconceptions:

- Orbiting astronauts are weightless because they do not experience a force of gravity OR weightlessness is due to the absence of air in space
    - I have not come up with a good way to explain this to students, but you can reassure them that gravity exists in space. You can explain that gravity is related to distance and mass, not

atmosphere/air.

- Astronauts are weightless because the force of gravity is reduced in space.
    - The earth's gravitational attraction at those altitudes is only about 11% less than it is at the earth's surface. If you had a ladder that could reach as high as the shuttle's orbit, your weight would be 11% less at the top. Put another way, a person who weighs 100 pounds on the earth's surface would weigh about 89 pounds at the top of the ladder.

(1) Introduction & Solar system demo:

Show the motorized solar system demo!

- Explain how the planets orbit the sun; that the path the planet takes is called an orbit.

Has anyone heard of the word “orbit” before? Can anyone explain what an orbit is?

- Hopefully someone will say something about the earth orbiting the sun or the moon orbiting the earth.
- An orbit is the path of an object around a point in space, for example, like the path the moon takes around the earth.
    - Possible follow-up: What shape are orbits?
    - Usually the shape a planet travels around the sun is oval or circle

Has anyone heard of “weightlessness” before? Have you experienced it?

- Hopefully the student will have ridden a roller coaster, airplane, or even an elevator that has given them the sensation of weightlessness
- Explain that it feels like you do not have any weight and try to get them to make a connection between these experiences -- in these cases, you are falling.

(2) Mini-activity: What is an orbit?/Why do things orbit? (15 mins)

Note: For the younger students **(Y)**, we may just want to stick with the first question: What is an orbit? For the older students **(O)**, they may already know that planets orbit around the sun and the moon orbits around the earth, but they may not understand why this happens.

Materials:

- Paper -- crumpled into a ball
- Tape
- Thread (~ 8 in)
- Pencil

Objective:

- Gravity is an invisible force **(Y)**
- Gravity is causes things to orbit in space
- Things orbit when they have some initial speed and an additional force (gravity) **(O)**

Procedure:

1. First, talk about what weightlessness is. It may help to show them the photos of astronauts experiencing weightlessness.
2. Ask if the students know why this doesn’t happen on earth. (Hopefully, they say something about gravity.) Does the sun have gravity? What about other planets? **(Y):** If they are not familiar with gravity, we can try to explain the concepts of “force” and “gravity.”
    a. **(Y):** One fun activity might be to have students act out “invisible forces.” Basically the students can stand facing each other and try to (i.e. pretend to) push and pull each other without touching to help them visualize an “invisible force.”

3. Tape the piece of string/thread to a piece of paper
4. Crumple the paper into the ball
5. Model an orbit by swinging the paper ball in a circle
6. **(O):** Ask why the paper ball moves in a circle.

Explain that orbit occurs because the paper ball has some initial speed (it is moving in some direction) and then it gets pulled toward the center by the string. *This is a model for a space shuttle orbiting the earth where the ball is the space shuttle and the string is gravity*.

7. There are two ways you can show this "initial speed/direction"

a. When the ball is "orbiting" let go of the string and see where the ball goes. The thread should leave a trail behind the ball so you can see the direction that it was traveling.
b. Make a loop on the other end of the string and put that loop around a pencil. Flick the paper ball in an "initial direction" and (hopefully) the ball will be pulled by the string to make a circular path.

Main point: When the space shuttle/station is orbiting, it is being pulled toward earth by gravity. Essentially, it is "falling" around the earth.

(3) Main activity: Astronauts -- Floating or Falling? (25 mins)

Materials:

- 2-liter plastic bottle
- Construction paper
- 50 cm of thin string or thread
- Astronaut cut-out
- Scissors
- Stapler
- Marker
- Tape
- Ruler

Objective:

- When both the person and the space shuttle fall (due to gravity), the person will appear to float because it is falling with the space shuttle (i.e. at the same rate).

Note: Instructions are copied from student worksheet. Easier to refer from student copy.

1. To create your model Space Shuttle, draw a thick red line four inches from the top of a piece of construction paper. Tape the paper lengthwise to the outside of a dry 2 liter bottle, so that the red line faces into the bottle. This area is now the back of the "Space Shuttle" bottle.
2. To create your model astronaut, cut out the rectangular picture of the astronaut located on the last page of the Student Worksheet. Fold the astronaut model in half, so that the astronaut has a front and a back, place the end of a 50 cm thread inside, and staple it together so that the string does not slip out. Do not cut the thread shorter!
3. Holding the thread, push the model astronaut into the bottle. Lower the model into the "Space Shuttle" bottle so that the astronaut's head is at the level of the red line in the bottle.
4. Keep holding the "Space Shuttle" bottle and release the thread that holds the astronaut. What happens to the astronaut in relation to the red line? Explain.
5. Pull the thread out of the bottle so that the astronaut's head is at the level of the red line once again. Hold onto the thread and bottle with your thumb and index finger. (See picture below.)
6. Ask your partner to stand across the room (about 20 feet away). Tell your partner to carefully watch the paper astronaut and the red line in the "Space Shuttle" bottle as you drop the bottle and thread (with astronaut) at the same time. Let go of the bottle and the thread at exactly the same time.
7. Where was the astronaut in relation to the red line in the "Space Shuttle" bottle during the fall?
8. Drop the "Space Shuttle" bottle and the paper astronaut four more times. Record your

observations in the data table each time.

9. Exchange places with your partner and repeat steps 5-8 again.
10. Based on what you saw, explain why an astronaut feels weightless in space, even if he/she is falling.

(4) Extension: Living with weightlessness (fill remaining time)

If there is time remaining, we can talk about space shuttles and space stations. For example, you can mention that there is an international space station that orbits the earth. Scientists conduct experiments to see what happens in microgravity/weightlessness. Can you imagine what it would be like to live in a free fall environment?

1. Make a list of all of the things that you do in a day. Discuss how these things would be different in a space shuttle or space station.

Examples:

- Sponge baths required because water droplets would not fall towards/on you
- Astronauts require a meal tray with velcro to secure food. The food is also packed in separate packages.
- Need to be very clean! Studies have shown that the population of some microbes can increase extraordinarily in microgravity and confined spaces.
- Need to be strapped to something while sleeping. “The sleeping bags are cocoon-like restraints attached to the lockers where crew provisions are stored”
- Lose muscle and bone mass very easily. Need to exercise: Using an exercise bike, treadmill (with straps that make it very uncomfortable!), or tension/bungee cords.