Gravity and Falling

How does gravity work?

About the Activity

Using a bucket with stretchy fabric stretched over it, allow visitors to experiment with marbles and weights to discover some basics about gravity.

Topics Covered

- Mass curves space.
- More massive objects curve space more so the force of gravity is stronger in the presence of more massive objects.
- Why things fall to Earth.
- All objects, regardless of their mass, will fall at the same rate into the same massive object.

Participants

- Adults, teens, families with children 7 years and up
- If a school/youth group, 9 years and up
- From one person to fifteen participants

Location and Timing

- Pre-Star Party: As an introduction to the night's observing.
- Scout troop or classroom: Form teams of 8 to 10 people and provide each team with a set of materials.
- Science Fair or Science Museum: Set up one or more tables with the demonstration materials. Have a club member at each table.
- This activity takes about 15 minutes

Materials Needed

- 2 buckets (13"/33 cm plastic planters), from a garden store
- 2.5 pound (1 kg) lead weight, from a fishing or sporting goods store
  ***See important safety note on lead weights in the Helpful Hints**
- 8 oz (225 g) lead weight
- 4 oz (100 g) lead weight
- 2 Pee-wee marbles
- 2 Shooter (one-inch/2.5 cm) marbles
- A few regular marbles
- 2 bungee cords
- 2 18" (45 cm) squares stretch fabric squares – Can be found at a fabric store. Make sure the fabric is lightweight and quite stretchy in all directions.
- Large towel or blanket

Set Up Instructions

- Secure the fabric onto the buckets with the bungee cords. Make sure the smoothest side of the fabric is facing up. The fabric on both buckets needs to be evenly stretched and stretched to approximately the same tension on both.
- The buckets MUST be placed on a level surface. It is helpful to set up on or over a "non-roll" surface, like grass, carpet, a blanket, or large towel, to avoid having to chase marbles all during the presentation.

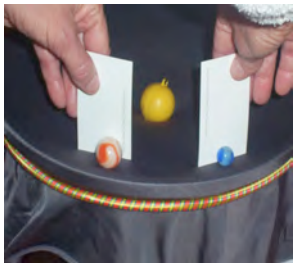
Detailed Activity Description

INTRODUCTION: Mass curves Space – Reason for gravitational acceleration

Introduction
How does gravity work? In the 1600's Isaac Newton developed the universal law of gravitation describing it as a force of attraction between objects that decreases with distance, and Albert Einstein in the early part of the last century developed the concept that matter curves space around it and this is why there is the force of gravity (as well as correctly predicting the existence of things like black holes and gravitational lensing of light). This concept has been verified by abundant observational evidence (see "Background Information" below).
This is one of a set of activities that illustrates various effects of gravity, or curved space. How much space curves, depends on two things: 1) How much mass is present. More mass, more curvature, therefore stronger gravitational attraction. 2) What the distance is from the center of the mass. Farther from the center of a massive object, space is less curved; therefore the gravitational attraction is less.
Take the two buckets covered with fabric and two different sized weights. Place one weight in the center of the fabric on each bucket. Notice that the more massive weight curves the fabric, representing space, more than the less massive weight. Notice also that space is curved the most nearest the weight and less curved toward the edge of the bucket. 

Falling Down / Falling In

Leader's Role	**Participants' Roles (Anticipated)**
To Say: Jump! Jump again! Why do you fall back to Earth every time? What's Gravity? What kind of a force is gravity? Can you throw a ball so that it doesn't come back down to Earth? Albert Einstein in the early part of the last century developed the concept that matter curves space around it and this is why there is the force of gravity. Let's see what that means.	 Gravity! What pulls us back to Earth. No
To Do: Set out the two buckets with fabric stretched over them. *To Say* : (Point to one of the buckets.) This is space, the "fabric" of space. There is space all around us everywhere, in all directions. This just represents one small portion of space. Einstein said that massive objects curve space around themselves. *To Do:* Place the small white 4oz weight in the center of one bucket – or ask a visitor to place it. *To Say* : Let's use this weight to represent Earth. What happens to space when we put Earth in it?	 It curves/dips

Leader's Role	**Participants' Roles (Anticipated)**
To Do: Place 2.5 lb (large blue) weight on fabric on the other bucket – or ask a visitor to place it. *To Ask:* Now, let's say this is the Sun and put it here in space. How much is space curved around *this*? Right the Sun has more mass than Earth: What is "mass"? So the Sun is more massive than Earth? *To Do:* Hand out a few marbles – two marbles per person. 	A lot more! How much material is in something; how much it weighs Yes.
Presentation Tip: When you or your visitors roll the marbles across the fabric of space, roll them so they do not bounce. **If working with children**, give one child two marbles and then have them pass the marbles around. **NOTE:** If fingers are dirty, greasy, wet, or sticky, both marbles might not be released at the same time. You would do better to use a card (like a business card) to hold the marbles back. 	
To Say : This is a model and is not to scale. These marbles represent small space probes. If we place one probe at the edge of this bucket and the other probe at the edge of the other bucket, and let them both go at once, which probe is going to fall faster toward the center? Why? Let's try.	The one going into the Sun. More mass – space is curved more. Roll marbles into Earth and Sun.
To Say : So this is what we mean when we say the force of gravity depends on how much mass is present. Mass curves space. More massive objects curve space more or less?	More

Leader's Role	**Participants' Roles (Anticipated)**
So the force of gravity is stronger or weaker?	Stronger
To Say : We said space is curved around Earth. If you jump off Earth and end up here (take a small marble and hold it just slightly away from the surface of the small white weight), are you going to stay here if I let go?	No. You'll fall in.
 So why do you fall to Earth when you jump?	Space is curved around Earth.

Extending the activity: Everything falls to Earth at the same rate

Key Message for your visitors to take home: All objects, regardless of their mass, will fall at the same rate into the same massive object.

Materials: 2 buckets covered with fabric; one large and one small marble; Small medium weight.

To Do: Place the 4 oz or the 8 oz weight on fabric of one bucket – or ask a visitor to place it. Take a small marble and a large marble. *To Say:* Standing here, if I drop a large marble and a small marble, which one is going to fall faster toward the Earth?	Guesses.
To Say: Now, let's say this is the Earth (indicating the weight). We're going to drop these two marbles from the edge of the bucket at the same time. What's different about these marbles?	Different sizes.

To Say : If we place both of these at the edge of this bucket and let them both go at once, which marble is going to fall faster toward the center? Why? Let's try. Did they both fall to Earth at the same speed? 	Guesses/neither. Space is curved the same for both. Roll marbles. Yes.
To Say : Space is curved around Earth the same for both marbles, so they both accelerate equally, in other words, they fall at the same rate. If I drop this large weight and this marble to the floor, which will fall faster? **Presentation Tip:** **If you actually drop the weights,** make sure you are dropping them on a soft surface, like a thick towel or blanket, to prevent damage to the surface or to the weights, and to prevent the marble from rolling away or the weight from rolling onto someone's foot. If something falls slower than something else, it will be due to the presence of air, rather than the fact that the object is lighter in weight (e.g. a brick and a feather). There would be no such difference on the Moon since there is no atmosphere.	Neither. They'll fall together.

Helpful Hints

*If you purchase lead weights, you **MUST coat them** before using them. Lead is a substance known to cause health problems and birth defects or other reproductive harm. Use Plasti-Dip™, with an undercoating of gray Plasti-Dip™ primer or similar products available at many paint and tool stores and online from http://www.quiltershusband.com/qhhtm/qhplastidip.htm.

1) The concept of "mass" may be difficult for your audience. Ask what they think it means. You might want to define "mass" as the amount of material that is in an object – the property that gives an object "weight" in a gravitational field.

2) When you or your visitors roll the marbles across the fabric of space, roll them so they do not bounce.

3) **If you are working with children,** a few pointers:
   - Give just one child the marble(s) and have the kids pass them around.
   - You might want to make it into a game:
     - If the marble falls off the edge of the bucket, the child's turn is over and they must pass the marbles to the next child.
     - After one child takes three marble rolls, their turn is over.
     - The winner is the child who can get the marble to orbit the longest time.
   - Try to make sure they have clean hands, if possible – dirty, sticky, or greasy hands will transfer to the marbles and the marbles will not roll as well
   - Keep a small container of water and paper towels nearby to rinse and dry the marbles as necessary

4) Let your visitors experiment with the weights and marbles – they will discover a lot with your guidance!

5) Some people may ask why the fabric of space is not black or why the weights or marbles are not always the right colors for what they represent. You can say that this is one of the limits of making models of the universe – we have to imagine some things. If the fabric were black, it would be harder to see the curvature of the fabric of space.

Background Information

A good basic discussion of Newtonian gravity as it relates to these demonstrations can be found at:
http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html

Einstein's general relativity states that space (actually space-time) is curved by the presence of massive objects and the path that mass, as well as light, takes through space is determined by this curvature. For more explanation and observational evidence for general relativity:
http://www.nasa.gov/worldbook/gravitation_worldbook.html
http://curious.astro.cornell.edu/question.php?number=649
And this article, "Gravity as Curved Space"
http://theory.uwinnipeg.ca/mod_tech/node60.html

GRAVITY ASSISTS: Your visitors might ask about how NASA uses gravity assists to add speed to a spacecraft. The Space Place provides a helpful description and activity to illustrate the process: http://spaceplace.nasa.gov/en/educators/gravityassist.pdf.
For more details about how gravity assists work:
http://saturn1.jpl.nasa.gov/mission/gravity-assist-primer2.cfm
For a more technical description:
http://www2.jpl.nasa.gov/basics/bsf4-1.htm

CURVED SPACE vs. GRAVITATIONAL FORCE:
How much space curves around *one* object depends on its mass, and the curvature of space decreases with distance from the center of its mass. This curving of space determines how another object will move around this object.

How objects move through space around *each other* is actually dependent on the mass of *both* objects involved and the distance between them. For example, a pair of stars orbiting each other will orbit their common center of mass – the "balance point" between them. Space curves around *both* objects, so they tug on each other – this mutual tug is commonly referred to as "gravitational force".