G-Force

Overview: Have you ever been riding in a really fast car and you almost feel "pushed" back into your seat because of how fast you start? Or been thrown forward when someone had to slam on the brakes? How about pushed to the side when the car took a fast turn? So … who pushed you? That's what this lab is all about.

What to Learn: You'll learn about centrifugal force, centripetal acceleration and g-force, and how to tell the difference between them.

Materials

- bucket
- water
- outdoor area
- clear tubing (about 12-18″ long)
- nylon or metal barbed union that fits inside the tubing
- soda bottle (empty)
- wine cork
- string

Lab Time

1. To make the cork accelerometer, fill an empty soda bottle to the top with water.
2. Modify the soda bottle cap as follows: attach a string 8-10″ long to a clean cork, like the kind from a wine bottle.
3. Hot glue the free end of the string to the inside of the cap.
4. Place the cork and string inside the bottle and screw on the top (try to eliminate the air bubbles). The cork should be free to bob around when you hold the bottle upside-down.
5. Now race around and see if you can predict where the cork is going to go. Complete the data table.

G-Force Data Table 1

Activity You Did	Which Way Do you Guess the Cork Will Move?	Cork Observations

Remember – it is measuring acceleration, which is the change in speed. It will only move when your speed ***changes***. The trouble with this accelerometer is that there are no measurements you can take – it's purely visual. This next activity in this lab is more accurate at measuring the number of g-s you pull in a sharp turn (whether in a vehicle or in a roller coaster!)

6. To make the g-force ring: (This quick homemade device roughly measures acceleration in "g's." We used it to measure the g-force on roller coasters at Six Flags Magic Mountain, and it worked just as well as the expensive ones you buy in scientific catalogs!)
7. Cut about a foot of tubing – the larger diameter tubing you can find, the easier it will be to read your measurements.
8. Fill your tube halfway with COLORED water (it's impossible to read when it's clear). Blue, green, red… your choice of food dye additive.
9. Make an O-shape using your barbed union to water-seal the junction.
10. Grab hold of one side and hold the circle vertical, with the barb-end pointing up.

11. Make sure there are equal amounts of water and air in your tube. Adjust if necessary.
12. Make a mark on the tube where the water meets the air with a black marker. This is your 0-g reading (relative, of course). No acceleration. Not a whole lot of fun.
13. Now, for your 1-g mark – measure up 45 degrees from the first mark. (If the top of the circle is 90 degrees, and the 0-g mark is zero degrees, find the halfway point and label it).
14. The 2-g mark is 22.5 degrees up from the 1-g mark.
15. 3-g mark is 11.25 degrees up from the last mark. And 4-g is 5.6 degrees up from the last mark. (See a pattern? You can prove this mathematically in college, and it's kind of fun to figure out!)
16. Now, if you have access to a car with a driver or a playground with swings and spinning things, hold the tube in your hand so that the water line starts at the zero mark. See how far it sloshes up when you accelerate and read how many g's you've pulled. We would have contests to see who could pull the most g's while spinning in a circle.

G-Force Data Table 2

Activity You Did	How Many g's Measured?	Observations

Reading

G-force is really just the force that you experience by being accelerated. Have you ever been riding in a really fast car and you almost feel "pushed" back into your seat because of how fast you start? Probably not, because most of us don't ride in cars that fast. More likely you've been "thrown" forward when someone had to slam on the brakes, or you feel pushed to the side whenever someone takes a fast turn. Whenever you feel these "pushes," that means you are accelerating or changing speeds.

The higher the acceleration, the harder the "push" feels. The reason I use quotation marks to describe the push is to describe the "push" you feel when you experience the g-force. This push you feel is actually just your own inertia wanting to maintain the motion (or rest) your body was already in. When you suddenly stop, your body wants to continue moving forward, but your sense of relative motion is set to the car as a stationary location.

When you feel yourself wanting to continue going forward, and the car is stopping you think of yourself as being "pushed" or "pulled" when you are really just trying to keep your original motion.

The same happens when you are turning, even when you are moving a constant speed. I know it seems confusing, but we need remember that velocity is a vector, meaning that it takes into account speed *and* direction. When you are turning at a constant speed, you are changing direction, and that directional change means your velocity changes, so you have an acceleration.

The concept of the "push" or "pull" is the same as braking: Your body wants to continue to move in a straight line. When the car is turning to the left, your body wants to go straight, but in relative motion to the car you appear to be moving to the right of the car, so you feel "pulled" to the right.

How does this all relate to "g-forces"? Well, like we learned before, the acceleration due to gravity is 9.8 m/s^2, or 32 ft/s^2. And the g-force that you experience is just a multiple of this number. For example, if you experience an acceleration of 19.6 m/s^2, you would divide this by 9.8 m/s^2 to get 2 g's. If you experience an acceleration of 48 ft/s^2, you divide this by 32 ft/s^2, and you get 1.5 g's. So it's just how many multiples of gravity's acceleration you experience.

How does acceleration relate to force? Through Newton's Second Law: F = ma! But there are different kinds of forces (and thus acceleration): centripetal and centrifugal. How can you tell the difference?

Centripetal (translation = "center-seeking"**)** is the force needed to keep an object following a curved path. Remember how objects will travel in a straight line unless they bump into something or have another force acting on them (gravity, drag force, etc.)? Well, to keep the bucket of water swinging in a curved arc, the centripetal force can be felt in the tension experienced by the handle (or your arm, in our case). Swinging an object around on a string will cause the rope to undergo tension (centripetal force), and if your rope isn't strong enough, it will snap and break, sending the mass flying off in a tangent (straight) line until gravity and drag force pull the object to a stop. This force is proportional to the square of the speed - the faster you swing the object, the higher the force.

Centrifugal (translation = "center-fleeing") force has two different definitions, which also causes confusion. The inertial centrifugal force is the most widely referred to, and is purely mathematical, having to do with calculating kinetic forces using reference frames, and is used with Newton's laws of motion. It's often referred to as the "fictitious force."

Reactive centrifugal force happens when objects move in a curved path. This force is actually the same magnitude as centripetal force, but in the opposite direction, and you can think of it as the reaction force to the centripetal force. Think of how you stand on the Earth … your weight pushes down on the Earth, and a reaction force (called the "normal" force) pushes up in reaction to your weight, keeping you from falling to the center of the Earth. A centrifugal governor (spinning masses that regulate the speed of an engine) and a centrifugal clutch (spinning disk with two masses separated by a spring inside) are examples of this kind of force in action.

Imagine driving a car along a banked turn. The road exerts a centripetal force on the car, keeping the car moving in a curved path (the "banked" turn). If you neglected to buckle your seat belt and the seats have a fresh coat of Armor-All (making them slippery), then as the car turns along the banked curve, you get "shoved" toward the door. But who pushed you? No one – your body wanted to continue in a straight line but the car keeps moving in your path, turning your body in a curve. The push of your weight on the door is the reactive centrifugal force, and the car pushing on you is the centripetal force.

What about the fictitious (inertial) centrifugal force? Well, if you imagine being inside the car as it is banking with the windows blacked out, you suddenly feel a magical ”push” toward the door away from the center of the bend. This “push” is the fictitious force invoked because the car’s motion and acceleration is hidden from you (the observer) in the reference frame moving within the car.

Exercises Answer the questions below:

1. Which accelerometer was better at giving a visual representation of accelerating?

2. Which one do you prefer? Why?

3. What activity did you do that created the most acceleration?

4. What does that tell you about acceleration?

Answers to Exercises: G-Force

1. Which accelerometer was better at giving a visual representation of accelerating? (the liquid in the tube)
2. Which one do you prefer? Why? (The liquid in the tube actually gives a numerical measurement.)
3. What activity did you do that created the most acceleration? (spinning around in a circle)
4. What does that tell you about acceleration? (Centripetal acceleration is much higher and easier to achieve than linear acceleration.)