Roller Coaster Physics Experiment You Can Do With Your Kids

By Aurora Lipper

The reason why things bounce, fly, zoom, and splat are described by the Laws of Physical Motion most kids learn in their high school physics class. But you don't have to wait until your kid hits puberty to have fun with physics – you can start right now. Kids across the globe use the law of gravitation everyday to put the zing in their games, from basketball games to skateboarding. Let's find out how they do it.

Let's take a look at the first law of motion. When you place a ball on the floor, it stays put. A science textbook will tell you this: *An object at rest tends to stay at rest unless acted upon by an external force.* Your foot is the external force. Kick it!

What about when the ball whacks into something? Checking back in with the science textbook: *An object in motion tends to stay in motion unless acted upon by an external force.* After you kicked the ball (external force), it flies through the air until it smacks into something.

But there are two other forces acting on the ball that you can't see. One force is air resistance. The ball is hitting the air molecules when it flies through the air, which slows it down. The other force is gravitational. Gravity is inherent in anything that has mass (including you!), but you need something the size of a planet before you can begin to see the effects it has on other objects. If you tossed your ball in space (away from any nearby gravitational pulls like black holes or galaxies), it would continue in a straight line forever. There aren't any molecules for it to collide with, and no gravitational effects to pull it off-course.

There is one more idea that you'll need to understand… acceleration. A ball at rest has a position you can chart on a map (latitude, longitude, and altitude), but no velocity or acceleration. It's not moving. When you decide to stir things up and kick the ball, that's when it gets interesting. The second your toe touches the ball, things start to change. Velocity is the change in position. If you kick the ball ten feet, and it takes five seconds to go the distance, the average speed of the ball is 2 feet per second (about 1.4 MPH).

The trickier part of this scenario has to do with acceleration, which is the change of velocity. When you drive on the freeway at a constant 65 MPH, your acceleration is zero. Your speed does not change, so you have no acceleration. Your position is constantly changing, but you have constant speed. When you get on the freeway, your speed changes from zero to 65 MPH in ten seconds. Your acceleration is greatest when your foot first hits the gas – when your speed changes the most.

There's an interesting effect that happens when you travel in a curve. You can feel the effect of a different type of acceleration when you suddenly turn your car to the right – you will feel a *push* to the left. If you are going fast enough and you take the turn hard enough, you can get slammed against the door. So - who pushed you?

Think back to the first law of motion. An object in motion tends to stay in motion unless acted upon by an external force. This is the amazing part – the *car* is the external force. Your body was the object in motion, wanting to stay in motion in a straight line. The car turns, and your body still tries to maintain its straight path, but the car itself gets in the way. When you slam into the car door, the car is turning itself into your path, forcing you to change direction.

This effect is true when you travel in a car or in a roller coaster. It's the reason the water stays in the bucket when you swing it over your head. Physical motion is everywhere, challenging toddlers learning to walk as well as Olympic downhill skiers to go the distance.

Let's try these ideas out.

Bucket Splash Fill a bucket half-full with water. Grasp the handle and swing it over your head in a circle in the vertical direction. Try spinning around while holding the handle out in front of your chest to swing it in the horizontal plane. Vary your spin speed to find the minimum!

Marble Vortex Curl a sheet of paper into a cone, leaving a small hole open at the bottom. Place a marble in the cone and find the speed you need to circle the cone in order to keep the marble in the cone. NOTE: This is an excellent demonstration of satellites. The satellite is the marble and the cone apex is the earth. If the marble moves too fast, it will fly out of the cone (which is equivalent to the satellite flying out of orbit and into space). If the marble speed is too slow, it will fall into the bottom of the cone (translation: satellite crashes into earth). There is a very specific speed the satellite must maintain to remain in orbit.

Ping Pong Curves Attach a clear, plastic cup to the end of a long dowel so that the bottom of the cup rests along the length of the dowel, near the end (when the dowel is lying flat on the ground, the cup points up). Insert a ping pong ball in the cup and grab the free end of the stick with your hand. Swing it partway through a circle and suddenly STOP. The ball should pop out of the cup in a line tangent to your circle at the point you stopped. Why does the ball not continue in a circle or stay in the cup?

> *Answer:* An object in motion (the ball) wants to stay in motion (a straight line) and is free to do so when you stopped. Initially, it goes in a straight line tangent to your arc, but then gravity takes over and down it goes to the floor.

Cork Accelerometer Fill an empty soda bottle to the top with water. Modify the soda bottle cap as follows: attach a string 8-10" long to a clean wine cork. Hot glue the free end of the string to the inside of the cap. 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.

> *To use the accelerometer:* invert the bottle and try to make the cork move about. Remember – it is measuring acceleration, which is the change in speed. It will only move when your speed *changes*.

Roller Coaster Physics This is the best way to learn about physics. All you need is a handful of marbles, several pieces of ¾" foam pipe insulation, a few rolls of masking tape, and a crowd of participants.

To make the roller coasters, you'll need foam pipe insulation, which is sold by the six-foot increments at the hardware store. You'll be slicing them in half lengthwise, so each piece makes twelve feet of track. It comes in all sizes, so bring your marbles when you select the size. The ¾" size fits most marbles, but if you're using ball bearings or shooter marbles, try it out at the store. (At the very least you'll get smiles and interest from the hardware store sales people.) lit most of the track lengthwise (the hard way) with scissors. You'll find it is already sliced on one side, so this makes your task easier. Leave a few pieces uncut to become "tunnels" for later roller coasters.

The next step is to join your track together before adding all the features like loops and curves. Join two tracks together in butt-joint fashion and press a piece of masking tape lengthwise along both the inside and the underside of the track. A third piece of tape should go around the entire joint circumferentially. Make this connection as smooth as possible, as your high-speed marble roller coaster will tend to fly off the track at the slightest bump.

Roller Coaster Maneuvers

Loops Swing the track around in a complete circle and attach the outside of the track to chairs, table legs, and hard floors with tape to secure in place.

Loops take a bit of speed to make it through, so have your partner hold it while you test it out before taping.

Start with smaller loops and increase in size to match your entrance velocity into the loop. Loops can be used to slow a marble down if speed is a problem.

Camel-Backs Make a hill out of track in an upside-down U-shape. Good for show, especially if you get the hill height just right so the marble comes off the track slightly, then back on without missing a beat.

Whirly-Birds Take a loop and make it horizontal. Great around poles and posts, but just keep the bank angle steep enough and the marble speed fast enough so it doesn't fly off track.

Corkscrew Start with a basic loop, then spread apart the entrance and exit points. The further apart they get, the more fun it becomes. Corkscrews usually require more speed than loops of the same size.

Jump Track A major show-off feature that requires very rigid entrance and exit points on the track. Use a lot of tape and incline the entrance (end of the track) slightly while declining the exit (beginning of new track piece).

Pretzel The cream of the crop in maneuvers. Make a very loose knot that resembles a pretzel. Bank angles and speed are the most critical, with rigid track positioning a close second. If you're having trouble, make the pretzel smaller and try again. You can bank the track at any angle because the foam is so soft. Use lots of tape and a firm surface (bookcases, chairs, etc).

Troubleshooting Marbles will fly everywhere, so make sure you have a lot of extras! If your marble is not following your track, look very carefully for the point of departure – where it flies off.

- Does the track change position with the weight of the marble, making it fly off course? Make the track more rigid by taping it to a surface.

- Is the marble jumping over the track wall? Increase your bank angle (the amount of twist the track makes along its length).
- Does your marble just fall out of the loop? Increase your marble speed by starting at a higher position.
- When all else fails and your marble still won't stay on the track, make it a tunnel section by taping another piece on top the main track. Spiral-wrap the tape along the length of both pieces to secure them together.

Since 1996, Aurora Lipper has been helping families learn science. As a pilot, astronomer, engineer, rocket scientist, and former university instructor, Aurora can transform toilet paper tubes into real working radios and make laser light shows from Tupperware.