Lesson: “What makes roller coasters go so fast?”

VIDEO TRANSCRIPT

EXPLORATION VIDEO 1

Hi, it's Doug! I want to talk about roller coasters. If you've had the chance to ride one, whether you're a roller coaster fanatic or maybe they make you feel sick to your stomach, either way, you probably know that no two roller coasters are exactly alike. Almost every theme park seems to have their own special ride, too. For me, when I was growing up, that was the Batman ride at Six Flags, which had no floor for your feet to rest on. You're literally hanging from the ride, and at one point it even does a loop and flips you upside down. This is Goliath, a roller coaster at Six Flags Great America, near Chicago in the U.S.A. When it opened in 2014, Goliath set a world record for the fastest wooden roller coaster in the world. Let's take a ride, shall we? Here we go. We're going to go up the first hill, right at the beginning of the ride. Woah, see how high up we are? Okay, are you ready? Here we go! I'm telling you, this ride is intense. It goes 72 miles an hour! That's the same speed as a cheetah, or as fast as a car cruising down the highway. Now, in some ways, a roller coaster actually has a lot in common with a car. Even each individual section on a roller coaster is called a car. There are seats, usually some kind of wheels on each car—even the speed of the roller coaster is similar to the speed that cars can reach. But there's something very weird about a roller coaster, something completely different from a car, and that's where they get their energy from. Every car has an engine, something that's powered either by gasoline or a battery. And its almost always under the hood of the car in the front. But

roller coasters, well, see for yourself. Looking again here at Goliath, each car only has some wheels on it and room for the people sitting inside it. And looking at even the front and the back of the roller coaster, there's no engine there, either. Roller coaster cars have no engine. None! So how is it that a roller coaster car moves if it doesn't have an engine? Where does a roller coaster car get its energy from? What do you think?

EXPLORATION VIDEO 2

So, a roller coaster has no engine, but how does it move? The hill is a clue. To figure this out, it's helpful to think less about cars and more about the experience of riding up a hill, like on a bike or on a skateboard. When you go up a hill, notice how you have to put in all this effort to get up the hill. It takes a lot of your energy. But once you're up there, it's almost no effort to come down. You just zip all the way down! Think about it. Going up a hill is almost like storing energy in yourself, isn't it? It sounds weird to say this, but it's true. Putting something up high is a way to store energy in something. I think part of what makes this feel weird is that all the other ways of storing energy are things like batteries, food, gasoline—actual things that store energy inside them. But it's true. Giving something height is another way that energy can be stored. It might be helpful to call this height energy. Scientists prefer to call this by a special name, gravitational energy, since it involves using the pull of gravity to make something start moving. But it's the same idea. The higher the hill you climb, the more energy you're storing. And so, when you start to come back down again, the faster or more energy you have. Here in San Francisco where I live, we're famous for streets that go up and down over big hills all around the city. People have to be careful. You come down one of these streets on your bike or your skateboard, you'll go flying. To demonstrate just how much energy you get from going down one of San Francisco's

hills, check this out. This person hitched a ride on the back of his garbage can. Let's see that again. By the way, this person didn't take very good safety precautions. They could have gotten badly hurt, so do not try this at home. But you get the idea. When you climb up to the top of a hill, whether on a bike or on a garbage can, that stores a lot of gravitational energy. And so, when you come back down, all that energy gets released. Once you understand that giving something height is a way of storing energy, you can totally make sense of how a roller coaster works. It doesn't need an engine on board to go fast and move along the track. All it needs is a big hill and something to pull it up that hill. Next time you ride a roller coaster, notice the first few seconds of the ride. There's always a hill you slowly climb up first, along with the clicking sound of a chain hooked up to a motor that's off to the side of the track. That's what's pulling you up that hill. That slow climb to the top of the first hill, that's all this gravitational energy being stored in the roller coaster. Because once you get to the top, all that stored energy gets released, zipping you through the rest of the ride. This whole idea of gravitational energy, or storing energy in something by giving it height, you're going to get to explore this idea more, even experiment and play around with it in the activity.

ACTIVITY INTRODUCTION VIDEO

In today's activity, you're going to use what you know about energy to build a totally new kind of roller coaster. Let's imagine there's this carnival company called Acme Amusements. They've asked Annie, one of their best engineers, to come up with the idea for their new ride. Annie thought, "Well, we all know about roller coasters, which are awesome. But there are also bumper cars, which are also awesome. Why not combine these two rides?" And so Annie designed a new invention she's calling the bumper coaster. Here's how it works. Riders sit in a

car at the top of the hill, but instead of a traditional bumper car, this car can roll. They'll roll down the track, then bump into an empty car at the bottom of the hill. But Annie's got to deal with one big problem. The only place to build this bumper coaster ride is right next to an alligator-infested swamp. Annie needs to find a way to make sure that the car with the rider doesn't end up as gator chow. So today, you'll make a model of the bumper coaster ride out of paper. Instead of cars, your model can use marbles, like these. There will be a marble at the top of the hill. We'll call it the hill marble. That's the car with the rider in it. The second marble will be the empty car. We'll call it the bumper marble. Your job is to make sure that when the hill marble rolls down and bumps into the bumper marble, the rider doesn't get eaten by the alligator. You'll get to experiment with this model to figure out how to do that. I'll show you how to get started, step by step.

ACTIVITY PART 1 STEP 1

To build one bumper coaster, there are four pieces of the track. So if you're in a classroom, you're going to form a group of four people, and each of you will work on one piece of the track. Each of you has a name, so go ahead and decide now who will be Klunk, who will be Boom, who will be Crash, and who will be Pow. If you're working alone, that's okay. You'll be building the whole coaster. When you're done with this step, click the arrow on the right.

ACTIVITY PART 1 STEP 2

Okay, get these supplies. Klunk, you're going to be making track one. Boom, you'll make track two. Crash, you'll make track three. And Pow, you'll make track four. But just get these supplies for now. Don't start building yet. We'll show you how to get started in the next step.

ACTIVITY PART 1 STEP 3

Okay, to get started, each person needs to fold their section of the bumper coaster. Even though everyone's tracks look really different, they all have a line running right down the center of the paper. What we're going to do is line up the edges and the corners of each paper and fold down the center of that line just like you see here. Once you do that, make a nice crease using your fingernail. Okay, go ahead and do this now.

ACTIVITY PART 1 STEP 4

Now, this next step is just for Crash and Pow. Boom and Klunk, you can watch what they're doing and help them out. Crash and Pow, on your track pieces, notice that there are these circles. We're going to poke holes in these in order to give the marble somewhere to sit on your track. To do that, slide the paper so the circle is slightly off your desk. Then, keeping one hand on the table and holding the paper in place, like this, take your pencil and use it to carefully and slowly poke a hole in the circle. It takes a little effort because you'll be poking through two pieces of paper. Be sure to do this for every circle on your track.

ACTIVITY PART 1 STEP 5

Now, let's get back to your tracks and make them sturdy. What you'll want to do is fold them in half, just like this. Make sure to line up the corners and the edges before you press down. Then, use your fingernail to make a really good crease. It should look like this when you're done.

ACTIVITY PART 1 STEP 6

Okay, now to create the sides of your tracks. You're going to want to fold each side so that it just barely covers the image of the track, like you see here. You'll press down and use your fingernail to make a really good crease. Notice that the track should be pretty stiff at this point, so you might have to press down hard. Then repeat this on the other side, like this. When you're all done, it should look like a U shape, like this.

ACTIVITY PART 1 STEP 7

All right, Boom, you're going to have to do something special to your track since it's at the bottom of the hill. Find the two dotted lines on the end your track, right here. Cut them like this; just be careful not to cut on the thick black line. Okay, as you cut on those dotted lines, when you're done, fold the black line, like this. All right, fold it in both directions and it should look like this when you're done.

ACTIVITY PART 1 STEP 8

Now it's time to start combining your track pieces. Klunk and Boom, you'll want to find the triangles at the end of your tracks and put them near each other, like this. Then get four paperclips ready. Crash and Pow, you'll look for the diamonds on your tracks. Put them near each other, like this, then you'll get four paperclips ready as well.

ACTIVITY PART 1 STEP 9

Okay, now we're going to connect the tracks. Klunk and Pow, each of you find the track pieces that have the solid black shape. Klunk, yours is the solid black triangle. Pow, yours is the solid black diamond. Open these track pieces up, like this. Then, slide in the other track that has the same shape. But as you do this, only slide it until you cover up the gray area, like this. Boom and Crash, while Klunk and Pow hold the connected pieces together, you're going to add each of the four paperclips to the tracks. To connect the track, you'll want to slide each paperclip over the paperclip marks, like this.

ACTIVITY PART 1 STEP 10

Okay, last but not least, time to create the alligator. Here's how to do it. Crash, you'll roll the sheet of paper up like this so that you cover the striped lines. Then, Pow, you'll put one paperclip here near the stars. Then pinch down the gray bar, like this. And after you do that, attach two more paperclips, just like this. When you're done, it should look like this. With one end closed and the other end, the alligator's mouth, wide open.

ACTIVITY PART 2 STEP 1

Okay, we're going to set up the track on a hill. And for that hill, we'll use the wall, or some kind of box, or a stack of books. It all depends on what you have available. To set up the track, you'll want some space on the floor to work. You'll want to bring these supplies with you to your workspace, and you'll also want to be sure to get these supplies.

ACTIVITY PART 2 STEP 2

Klunk, use your ruler to measure 20 centimeters up from the ground. Now, we're using a box, but you might be using books or a wall; that's okay. Boom, get a sticker and put half of it on the part of the track that says "high," like this. Then press the other half of the stick on the box right at where 20 centimeters is.

ACTIVITY PART 2 STEP 3

Okay, now you're going to attach the alligator to the track. Pow, put half of the stick on the end of the track that says “Danger” and place it inside the alligator's mouth, but just up to the black bar, like this. Then press the sticker down inside the alligator's mouth. Once you've done this, you can go to the next step.

ACTIVITY PART 2 STEP 4

You're almost done setting up. Klunk and Boom, you're going to attach these last pieces, the ones with stars on them. Klunk, first make sure that the black star is flat on the ground, like this. If these little flaps with the gray triangles are sticking out, make sure they're tucked inside the track, like this. That'll help the marble roll smoothly. Then, to attach the tracks, Boom, you're going to slide the striped gray part of the other track underneath, like this. Then add two paperclips, like this. Now your track is ready.

ACTIVITY PART 2 STEP 5

Practice. Boom and Klunk, you'll take turns placing one marble at the top of the hill and releasing it. Crash and Pow, help them out. You can each take turns tilting the alligator to get the marble out. Then go to the next step once you've practiced.

ACTIVITY PART 2 STEP 6

During your practice runs, I'm guessing that your hill marble always ended up in the alligator's mouth. So now let's add the bumper marble. But, where to put it? Annie has the idea that if we put the bumper marble fairly far away from the alligator mouth and not close to it, that will stop the hill marble from being eaten. What do you think? You can experiment to find out. You'll do three experiments to see which distance from the alligator's mouth will give you the best results. You'll do each experiment four times, or four trials. You can take turns doing the four trials so that each person gets a turn with the marbles.

ACTIVITY PART 2 STEP 7

Have a look at this question on your worksheet about the distance experiments. Go ahead and answer this, then discuss with someone near you.

ACTIVITY PART 2 STEP 8

Annie has another idea for how to avoid the alligator mouth. Instead of focusing on the bumper marbles, she thinks that if you put the hill marble at a lower height, that might stop the hill marble from being eaten. What do you think? Try these height experiments to find out. You'll do

each experiment four times, or four trials. As you do, take turns being the one to release the marble.

ACTIVITY PART 2 STEP 9

Have a look at this question on your worksheet about the height experiments. Go ahead and answer this, then discuss with someone near you.

ACTIVITY PART 2 STEP 10

Okay, you can head back to your seat if you haven't already. Be sure to watch the next video, and if you have time, after the video there will be one more bumper coaster experiment you can try.

ACTIVITY INTRODUCTION VIDEO 2

So, what did you find out as you tested your model of a bumper coaster? Were you able to stop the hill marble from being eaten by the alligator? Well, here are some things we noticed. Changing the distance of the bumper marble did make a little bit of a difference for us, but not much. It was barely noticeable. The marbles were eaten every time. Instead, changing the height of the hill marble made the biggest difference, and that makes sense based on everything you've learned, right? Giving something height is a form of storing energy. So, by placing the hill marble higher up on the hill, you gave it more energy. When it rolled down and smacked into the bumper marble, it transferred a lot of that energy, and so it made the bumper marble go faster and farther—oops, right into the alligator's mouth. We did find one way to avoid the alligator's mouth, and that was to do this: release the hill marble from a low height. That way, we didn't

store too much energy in it, so that when it hit the bumper marble, there was just barely enough energy to get it to roll right up to here and then stop. While that solves the problem of the alligator mouth, it's not the best solution for an amusement park ride. Keep in mind, an amusement park ride is supposed to be fun and exciting. Annie feels like, if this were real life and the riders were at a similar height as the hill marble, sure, they'd avoid the alligator's mouth, but this isn't very fun because there's so little energy. You don't get to feel the rush you get from speeding along the track. Annie really likes the crash of the two bumper coasters together. She wants to keep that part. But she also wants a ride that has a bit more energy to it, something that lets you start from higher up on the hill. It's way more fun that way. So, if you have time to keep exploring and brainstorming, think about this: what could you do to make this ride fun but still stop the hill marble from going into the alligator's mouth? What do you think?

ACTIVITY PART 3 STEP 1

Annie got to wondering again: what if we added more collisions? Will adding more collisions keep the Hill Marble from getting eaten? There's only one way to find out. Get your final supplies, and try the collision experiments on your worksheet.

ACTIVITY PART 3 STEP 2

Go ahead and circle the results of your collision experiments. Write your explanation and then discuss.

ACTIVITY PART 3 STEP 3

There's one more video and discussion you can do. But now might be a good time to clean up. So, if you're ready to put things away, Pow, you can remove the paperclips at the start. Klunk, you can gently remove the bumper coaster track from the wall or the stack of books. You'll use these tracks again for the next Mystery, so be sure to save them. You can stack them like this, paperclip them together, and then store them somewhere safe and out of the way. If you're all finished cleaning up, go to the last step.

ACTIVITY PART 3 STEP 4

If you haven't already, now would be a good time to return to your seat. Discuss this question. Then be sure to watch the final video.

WRAP-UP VIDEO

So, what did you find out as you added more marbles to the bumper coaster track? Here are some things we noticed. Adding more marbles to the track definitely stopped the hill marble from going into the alligator's mouth. In fact, by adding enough marbles, we could even start the hill marble from a pretty high place and still avoid the alligator's mouth. Annie would find this a great design. It meets her criteria that the track still be really fun while also avoiding the alligator. But why does introducing more marbles stop the hill marble from going into the alligator's mouth? After all, when one thing has energy and then collides or bumps into another thing, that energy gets transferred, causing the second thing to start moving. But, as you can see from the experiment, you just did, not all of that energy from the hill marble gets transferred, does it? If all

the energy got perfectly transferred between each marble, then both of the extra bumper marbles would have gone into the alligator's mouth. But not all of the energy from the hill marble did get perfectly transferred. It didn't keep moving forward. Along the way, some of the energy from that hill marble got transferred to other places. For example, did you notice this? As each marble collides with the next marble, you hear a sound. That sound travels through the air and goes out toward your ears. As you'll learn if you study sound in the Waves of Sound unit, there is evidence that sound itself is a form of energy. So, by adding marbles along the track, each time they smack into the next marble, the sound that's created is a little bit of energy from the hill marble that's now traveling not forward but toward your ear. This explains why each marble, as it moves forward, doesn't move all the way to the alligator's mouth. Some of the energy from the hill marble is being transferred to the air around the marbles, not just traveling forward from marble to marble. In fact, that's something you can notice next time you see anything around you bumping into or colliding with something else. There's always a sound. Sometimes, it's a soft, barely noticeable sound, like the sound of your head falling into your pillow after a long day. Other times, it's a lot louder, like the sound of a belly flop. Oof, that looks painful. But every time there's a collision, there's a sound, and it's some of the energy being transferred from the object to the air around it. See if you can notice that next time you see a collision. Have fun, and stay curious!