mystery science

Lesson: “Why is the first hill of a roller coaster always the highest?”

VIDEO TRANSCRIPT

EXPLORATION VIDEO 1

Hi, it's Doug! Check out this roller coaster ride for a second. This guy is having a lot of fun. Now, one of the things that makes coasters so fun are all these ups and downs. When roller coaster designers create rides, they have to figure out how high to make the hills. So let's look at a few roller coaster designs to see how high the hills are. This is the layout of a roller coaster called The Intimidator. The cars start out in this building and they go up this big hill. They roll down. They swing to the right. Turn back around. Then they make their way up another hill, and so on. The cars, you can see, they go through a bunch more twists and turns on this ride. There are a few low hills, which you can see pointed out here. Out of all the hills in the ride, though, the very first hill is definitely the highest. Let's look at another roller coaster; this one's called The Behemoth. Its cars start in this building. They immediately swing to the left. Climb up this giant hill. Roll downhill really fast. And then go up another pretty tall hill, and so on. Now you see, there are lots of hills in this ride. If I point them out, there are a lot. Most of them are pretty high, too. But the highest of them all was this first hill that the roller coaster goes up. So in both of the layouts we looked at, the first hill was the highest—that's not a coincidence. You could look at 1,000 more roller coaster designs and their highest point will always be their first hill. Why do you think that is? Why is the first hill in a roller coaster always the highest?

EXPLORATION VIDEO 2

Here at Mystery Science labs, I'm setting up a model coaster to figure out: why is the first hill always the highest? Now, right now, I've only built one hill, the first high hill, so I still need to make the second hill. I'm going to make this hill lower than the first one, just like a real roller coaster. All right, so let's see what happens when I drop a marble off the first hill. Ooh, makes it. Made it over that hill. That's not surprising. We knew that would happen, right? But what if the second hill is higher than the first hill, like this? Now what will happen when I let go? I'm going to give you 10 seconds to turn to your nearest classmate and predict what you think is going to happen when I let go of the marble. OK, let's see. Oh, it doesn't make it over, does it? So why does the model make it over the lower hill but not the higher hill?

EXPLORATION VIDEO 3

So, why didn't the marble make it over the higher hill? Why does the first hill have to be the highest on a roller coaster? You all had a chance to discuss, and, hopefully, you're thinking about it in terms of energy. When the marble is dropped from a certain height, like, say, from here, there's a certain amount of energy you've stored in it by placing it up this high. The higher it's dropped from, the more energy you store in it. But that's all the energy it gets, no more. Watch, by the time the marble reaches the bottom of the first hill, it's got all the energy it was going to get from being dropped. You know, it's kind of like the marble has an energy meter, and at this point, it's fully charged. In order to climb the second hill, the marble is going to use that energy, like this. See, it's going up, and it's losing energy. Since the second hill is taller than the first, the marble doesn't have enough energy to get to the top. You can see here that this marble was only able to get halfway up there. In fact, it can't roll up higher than the height of the first hill.

You can actually see the same thing on the swings at the playground. If you pull back the swing like this and then you drop it, see, the swing isn't going to swing back any higher than where it started from. Let me show you that again. The swing is going to be dropped from here at the green line. When this boy's swing comes back, he's not going to go any higher than that line. Watch. Did you see that? Now, instead of a swing hanging from a beam like you see here, imagine we had a bowling ball. And imagine if you took your hands and you pulled back the bowling ball so that it was ready to swing. But now you put it against your forehead like this kid is doing here. So you see that he's got a bowling ball on a string, pulled back and ready to swing. What's going to happen when this guy lets go of the bowling ball? Is it going to swing back and hit his face? Well, let's find out, you ready? Ooh. No, it didn't hit him. He looks a little worried, but he doesn't need to be worried. It actually can't hit him. The bowling ball can't swing higher than the height it was dropped from. So what does the motion of the roller coaster, a swing, and a bowling ball on a chain all have in common? They all get their energy from starting up high. They're getting their energy from height. And that energy isn't enough to take them any higher than where they started from. Now, I should note, the bowling ball or the swing could've gone higher, and so you do have to be careful with this, because if someone pushes on you, rather than just lets you go, watch what happens. See, this dad is pushing on his son each time the swing comes back, and so this little guy is getting extra energy from his dad's pushes, making him actually go higher and higher with every swing. So, to sum things up, a roller coaster gets all its energy from that first big hill. The energy stored from going up that big hill is what gets the roller coaster all the way to the end of the ride. If you made the second hill the biggest hill, the roller coaster wouldn't make it over. That's why the first hill in a roller coaster is always the highest. Today, you're going to get a chance to solve another fun problem using the idea of height energy. Watch the next video to find out what the activity is.

ACTIVITY INTRODUCTION VIDEO

In today's activity, you're going to create the next version of the bumper coaster—a bumper coaster with hills. The first version that you built, the one from the last activity, was just one big downhill. Now, your ride will have ups and downs, just like a real roller coaster. Thankfully, this time there are no alligators. Instead, your goal will be a little different. You and your team will have two marbles again, but this time, both marbles will have riders, and your goal is to figure out how to get both marbles into the cup at the end of the track. I'll show you how to get started, step by step.

ACTIVITY PART 1 STEP 1

To build the new parts of your bumper coaster, there are four more 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 just be creating all the new parts of your bumper coaster. When you're done with this step, click the arrow on the right.

ACTIVITY PART 1 STEP 2

Okay, get these supplies. Each person has a different track worksheet, so find yours. But just get these supplies for now. Don't start building yet. You'll get marbles and a second worksheet after you build your track. 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 track. Even though everyone's tracks look 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 corners of each paper and fold down the center of that line. And make a nice crease when you do, just like this. Go ahead and do this now.

ACTIVITY PART 1 STEP 4

On your track pieces, notice 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 that 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. But it should look like this when you're done.

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 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 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 done, it should look like a U shape, like this.

ACTIVITY PART 1 STEP 7

To make this track piece into a hill, you need to make a few small cuts. Everyone, find these four dotted lines on your track and then cut along these dotted lines. Just be sure to stop when you get to the black bar. When you're done cutting, bend on the black bar to start to make the hills, like you see here. It should look like this when you're done.

ACTIVITY PART 1 STEP 8

Now it's time to start putting all your track pieces together. Crash and Pow, you'll put yours together first. Find the hearts at the end of your tracks and put them next to each other, like this. Crash, put the black heart over the gray heart until the stripes are covered. Hold it there, then, Pow, you put four paper clips on the tracks to secure them wherever you see the gray paper clip marks. Klunk and Boom, you'll do the same thing with your two track pieces, except with the three-leaf clovers. Klunk, be sure to cover up the gray stripes. And Boom, you'll paper clip the tracks together.

ACTIVITY PART 1 STEP 9

Your tracks are almost ready. Boom and Crash, find the raindrops on the tracks and put them next to each other. Boom, put the black raindrop on top of the gray one until the strips are covered. Crash, add two more paper clips where the tracks overlap.

ACTIVITY PART 1 STEP 10

All right, now it's time for the hills. For this step, first, everyone just get their hill. Klunk and Boom, you'll make the medium hills. Crash and Pow, you'll make the low hills. Once you've got these, go to the next step to start building.

ACTIVITY PART 1 STEP 11

Now we're going to start building the hills. The low and medium hill pages look a little different from each other, but they're folded in the same way. So, first, fold your page on the thick center line, like this. Be sure to line up the edges before you fold and use your fingernail to make a good crease. Then, take this edge of your sheet and bring it up to the line where this arrow points. Press down to fold it, like this. Give it a good crease when you do. Crash and Pow, your low hill sheet looks a little different, but just follow the arrow. After making a good crease, unfold it, then do the same thing to the other side. Once that's done, fold the whole page down, like this, so that it's folded in half. Line up the edges and make a good crease. When you're all done, they should look like this.

ACTIVITY PART 1 STEP 12

Now it's time to create a place on the hill to hold your bumper coaster track. To do that, cut along both of these dotted lines, like this. Be sure to stop cutting at the stop signs. Then, open it up. You're going to push down the gray box, like this, and pinch the part that you put down to flatten it. To give it a good crease, I suggest you lay it on the table and run your fingernail over it. Then, to make your hill stand up, open up the folded paper at the bottom and tuck in the striped side, like this. When you're done, they'll stand up, like this.

ACTIVITY PART 1 STEP 13

Okay, now you'll attach your hills onto the hill holders. First, Klunk, you'll cut the hill holder in half along the center dotted line. Then, Klunk and Boom, you'll attach each of the medium hills, like this. Put the medium hills on the striped part of the hill holder. And then put one paper clip on each side of the hills, like this. Now, Crash and Pow, you'll do the same thing but just with the low hills. Put the low hills on the striped part of the hill holder and put one paper clip on each side. They'll look like this when you're done.

ACTIVITY PART 2 STEP 1

Just like in the last Mystery, we're going to set up the first part of the track on a hill. And for that, we'll use the wall, or some kind of box or a stack of books, depending on what you've got around. You'll want to find some space on the floor to work. Bring these supplies with you to your workspace, the new tracks you made. And you'll also want to be sure to get these other supplies, including your tracks and alligator from the last Mystery.

ACTIVITY PART 2 STEP 2

Everyone, lay out your tracks, like this, making sure you've got enough room to work. You'll put the new tracks you made here, including the hills. Then you'll put the beginning of the track that you made in the last Mystery, here, and the end of the track, the part with the alligator, over here.

ACTIVITY PART 2 STEP 3

Okay, now let's start putting the pieces together. First, we'll attach the high hill. Klunk, use your ruler to measure 20 centimeters up from the ground. Boom, get a sticker and put half of it on the high end of the track. Stick it where Klunk has measured, like this. It should look like this when you're done. At the same time, Crash, carefully remove the old tracks from the alligator. You won't need these, so put them off to the side, then take the alligator and turn it over so you see the stars. This isn't an alligator anymore, it's a goal. Pow, put half of a sticker on the black goal bar, like this. Then put it inside the goal. Press down on the sticker to attach it.

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 track underneath, like this. Then add two paper clips, just like this.

ACTIVITY PART 2 STEP 5

Now we'll give the bumper coaster hills. Klunk, find the part of the track labeled Star Valley, and hold it down, like this. Boom, find the part of the track labeled Clover Hill, and lift it up, like this. Pow, if you can see a gray triangle, pinch the track so that the triangle is hidden inside the track. Crash, put the medium hills in place, and push down the tracks in the hills. Klunk, make sure the valley stays on the floor. If it doesn't, work together to adjust the pieces until the valley is flat.

ACTIVITY PART 2 STEP 6

Now we'll put the low hills in place. Then, it'll be all ready to experiment with. Klunk, hold down the Raindrop Valley. Boom, lift up Heart Hill. Pow, if you can see a gray triangle, pinch the track so that the triangle is hidden inside the track. Crash, put the low hills in place. Push down the tracks in the hills. Klunk, make sure the valley stays on the floor. If it doesn't, work together to adjust the pieces until it's flat.

ACTIVITY PART 2 STEP 7

Do a practice test. Klunk, release one marble from the high spot, the top of the hill. The marble should roll into the goal. But if the marble doesn't make it to the goal at the end, something's a little off with your track. Follow these engineering tips to double-check that everything is correct.

ACTIVITY PART 2 STEP 8

Now that your track is working, Annie needs to figure out where to put the bumper marble on the track so that both marbles reach the goal. Do experiments one through four on your worksheet. For each experiment, you'll do four trials. You'll always release the hill marble from the high hill, but you'll place the bumper marble at different places on the track. Take turns releasing the hill marble on each trial so that everyone gets a chance to experiment.

ACTIVITY PART 2 STEP 9

If you haven't already, you can return to your seat now. Then answer these questions on your worksheet.

ACTIVITY PART 2 STEP 10

Discuss.

WRAP-UP VIDEO

Hi, this is Traci. I work at Mystery Science and I'm one of the people who helped design this activity. We hope you had fun and learned a lot. I've been experimenting, too. And here are some things that I noticed. When the bumper marble was down in the valley, I could never get both marbles to the goal. The hill marble would roll down the first hill, over the top of the second hill, and down into the valley. Then it would collide with the bumper marble with a loud click. Both marbles rolled, but they couldn't make it over the top of the next hill. When the marbles collided, the hill marble transferred some of its energy to the bumper marble. And as you learned about in the last Mystery, some of that energy was also transferred to the air and became sound. So there just wasn't enough energy left for both marbles to reach the goal. So, putting the bumper marble in the valley didn't work. But that's okay. Part of being an engineer is seeing when things don't work and then learning something from that. So then, I tried putting the bumper marble at the top of a hill. When I placed the bumper marble on the medium hill, then both marbles made it to the goal. And when I placed the bumper marble on the low hill, the same thing happened— both marbles made it to the goal. So, why do they both make it this time? Well, the starting hill marble had enough height energy to carry it over the top of the next, lower hill. When the marbles collided, energy from the hill marble transferred to the bumper marble, just like before. And just like before, some of the energy was transferred to the air around the marble and became sound. But this time, something was different. This time, the bumper marble had energy of its very own. Since you placed it up high, it has high energy

stored in it. The hill marble gave the bumper marble a little push and the bumper marble started rolling downhill, using that high energy. And that's why both marbles reached the goal. So, you figured it out: the criteria for the bumper coaster, our way of deciding if it worked or if it didn't work, was to make sure all the marbles made it to the goal. And now we know how to do it. The bumper cars always need to start at the tops of hills. That will give the ride enough energy to make sure that everyone has fun and everyone makes it to the goal. Have fun, and stay curious.