KID: This is a Curio from Brains On, where we're serious about being curious.

GIRL 1: Brains On is supported in part by a grant from the National Science Foundation.

[MUSIC PLAYING]

MOLLY BLOOM: You're listening to Brains On from American Public Media. I'm Molly Bloom. One of the best parts of working on this show is reading the many emails and letters we receive from our listeners every day. They're brimming with curiosity, and fun, and emojis, lots of emojis. A few weeks ago, we got two emails that were so similar and so intriguing, we had no choice but to investigate. The first one was from Uma.

BOY: Hi, my name is Uma. I'm nine years old. And I live in Harvard, Massachusetts. The other day, I was riding the bus to school, and there's a flag flying around. I was wondering that if the fly was just hovering there in the middle of the bus, shouldn't it crash? The bus is moving fast, and the fly is not connected to it or sitting down like everyone else. If it did, would it crash into the back or the front? Thanks.

MOLLY BLOOM: And the second was this one from Hazel and Eleanor.

GIRL 2: And we're from Portland, Oregon. And I'll let them in. If a bee flies into a moving car, does it need to fly as fast as the moving car while it's inside or can it just hover? Bye.

MOLLY BLOOM: These are the kind of questions that can send your brain in circles. So, we enlisted the help of someone very comfortable with mind-bending questions.

SANG KYU KIM: Sang Kyu Kim, I've taught physics at Macalester College for the last 50 years. So I'm a long-time teacher.

MOLLY BLOOM: So what's the fate of a hitchhiking bug on a bus? The short answer is this.

SANG KYU KIM: The fly is simply hovering in the air. And the air is carried by the bus.

MOLLY BLOOM: So, no. If the fly is in the bus and the bus is going down the street at 30 miles per hour, the fly itself is not flying through the air fast enough to keep up with the bus. It's just hovering there in the air that's carried by the bus. But also, the fly, the bus, the kids on the bus, they're all moving through the air at 30 miles per hour because that is how fast they're moving through space. But also, maybe the fly isn't moving at all. That's because it's all relative. And these questions from Uma, Hazel, and Eleanor, and their answers are very complex.

SANG KYU KIM: This is the kind of question Einstein thought about. So it's a profound question. I want them to know that. [LAUGHS] They're asking me very profound questions.

MOLLY BLOOM: When Albert Einstein posed these three questions and did thought experiments, he came up with something called the theory of relativity, which was really a brand new way of thinking of time, space, gravity, and the universe itself.

SANG KYU KIM: Essentially, what Einstein said is motion and rest are relative concepts.

MOLLY BLOOM: It all depends on how you look at this situation.

SANG KYU KIM: Relative to the bus, if you're on the bus, you are at rest. But if you're on the ground, then the bus is moving.

[HORN HONKS]

MOLLY BLOOM: So you're sitting on the bus that's driving down the road. In relation to the bus, you're not moving. You're sitting still. You look around at the floor or the seat in front of you, and it's all staying put.

MAN: Is that gum down there?

MOLLY BLOOM: But let's say I'm standing on the sidewalk, and I see you sitting on the bus through the bus window as you go zooming by.

MAN: Hi, Molly.

MOLLY BLOOM: I'd definitely say you were moving, right? That's because relative to me, you were moving. Here's another example.

SANG KYU KIM: When you're on an airplane, especially if the flight is very smooth, and you are flying over the ocean, and you don't see anything underneath except water, then you look out the window, and you feel like the plane is not moving. So there's no sensation of motion. But the plane is moving. So it turns out, you can't tell the difference whether you're moving or at rest. That's called Einstein's principle of relativity, that motion and rest are relative concepts. So you are at rest relative to the wall, to your chair, but you may be in motion relative to something outside.

MOLLY BLOOM: So what about that bee flying outside the car window?

[MUSIC PLAYING]

SANG KYU KIM: If you are the bee and you are moving just as fast as the car from the ground, when the bee looks at the car, the car is not moving. So for somebody who is in the car, the bee is not moving either, just constantly at the same spot. It depends upon the frame of reference, who is observing.

MOLLY BLOOM: So like the fly on the bus, it's all relative. But if the bus were to quickly stop or turn, the fly and the people inside would feel the effects. We'd all slide forward or to the side, for instance.

SANG KYU KIM: When Einstein said the effects of motion and rest are indistinguishable, he's talking about uniform motion. Only if you are moving in a constant speed in a straight line, you can't tell whether you at rest or moving. But if you apply the brakes--

[TIRES SCREECHING]

--you can tell. Because you are no longer in uniform motion.

MOLLY BLOOM: Now that you're starting to grasp relative motion in cars and planes, ponder this.

[MUSIC PLAYING]

Even when you are sitting on the floor, no vehicle in sight, you're still moving relative to something. After all, the Earth is constantly spinning. You just don't feel it because everything around you is moving just as fast as you are. Not only that, but this spinning planet is also making large circles around the sun, so it's flying 67,000 miles per hour relative to the sun. And the galaxy our whole solar system is in is moving relative to other galaxies. So depending on how you look at it, nothing is actually still anywhere in the universe. Try explaining that to someone next time they say you need to sit still.

So once you can wrap your mind around this idea that everything is relative, that things change depending on who is observing and from where, you're ready to start tackling some really big questions about the nature of the universe itself.

SANG KYU KIM: When you push that principle of relativity deeply, it eventually shows you that time is relative.

MOLLY BLOOM: Einstein figured out that not only is motion relative, but time and space are relative. Part of this idea is that if you travel very, very, very fast, time will move slower for you. So imagine you have two clocks set to the exact same time.

MAN AND WOMAN SPEAKING SIMULTANEOUSLY: Ready, synchronize.

MOLLY BLOOM: Now, imagine you took one of those clocks and sent it up into space on a super fast rocket. And the other clock is sitting on Earth. On the ship, time flows normally, but the rocket is circling the planet at near light speed. And after, say, a year of this, when that rocket lands, the clocks will be different.

MAN 2: Gadzuks.

WOMAN: They're out of sync.

MOLLY BLOOM: So even though only one year passed on the rocket, five years may have passed here on Earth. And if this sounds nuts, consider the fact that we actually see this happen with satellites. As they circle the planet, they slowly fall out of sync with clocks on Earth and need to be adjusted, just as Einstein's work predicted.

SANG KYU KIM: Relativity.

MOLLY BLOOM: Right? I know, it's mind-bending.

[MUSIC PLAYING]

These revolutionary ideas of Einstein's started in his imagination. He took what he observed and knew about the world, and turned them over and over, and looked at them from different angles, until these thoughts started to emerge.

SANG KYU KIM: Einstein thought pure thought was so powerful. And he kept saying you can understand the universe by pure thought. Curiosity, that's a starting point. Like these girls, they are curious, they observe something and want to know. They want to be able to explain it.

MOLLY BLOOM: So next time you see a fly hovering on the bus, or a bee flies through the window, or something else catches your eye and your imagination, let it go, and see where your thoughts can take you.

[MUSIC PLAYING]

That's it for this Brains On Curio. We had help this week from Meg Martin, Eric Wrangham, Max Nestrak, Marquita Fornof, Julia Majors, and Emily Allen. We'll be back next week with more answers to your questions. Thanks for listening.

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