But Why: A Podcast for Curious Kids

How do boats float?

December 16, 2022

Jane 00:21
I'm Jane Lindholm, and this is But Why: A Podcast for Curious Kids, from Vermont Public. On this show you ask the questions and we get to find the answers. And we love it when you send us off on field trips! As you can hear, I am not in a recording studio today. I'm on the Staten Island Ferry in New York, and today we're going to learn about how boats float.

Announcement 00:43
May I have your attention, please. Welcome aboard the Staten Island Ferry. Please take a moment and pay attention to the following safety announcements.

Jane 00:53
The Staten Island Ferry is a passenger boat. Some ferries carry cars, some carry animals, some carry all kinds of cargo. But this one just carries people to and from to different islands in New York. Some people use this boat every day just to get to work, or to a store or even to get to school. But we wanted to ride this ferry because it's fun. And learn a little bit more about how a boat like this can stay afloat with so many people on it.

Finn 01:23
My name is Finn. I'm from Cambridge, Massachusetts. I'm six years old. How do boats float?

Leo 01:31
I'm from British Columbia. My name is Leo. And I have a question. Why do boats float?

Ava 01:38
My name is Ava. I'm five years old. I live in Canada. And my question is how do boats float?

Tomas 01:46
My name is Tomas. I'm seven years old. I live in Barcelona, Spain. And my question is why ships don't sink.

Jane 01:55
It was too loud on the ferry. So we hopped off and headed back to our studio in Vermont, and called up Fahad Mahmood. He's a professor of physics at the University of Illinois. Physics is the study of stuff, and the stuff that stuff is made of, and how all of that stuff interacts with other stuff! But physicists don't call it "stuff," they call what everything is made out of "matter." So physics is the study of matter.

Fahad Mahmood 02:26

It's the study of matter and energy around us. So, broadly defined, I would say, even things that you can't see. For example, the way I'm talking and the way this signal is going to your yours right now, I can't see that, but I can sort of hear that. And so that is physics, right? How is sound traveling from your speakers into your ears? That is physics.

Jane 02:49
And by the way, if you want to know more about how the sound of my voice travels into your ears, and why it can sometimes be so strange to hear our own voices back on the radio or a microphone, we have an episode all about that. If you scroll back through your podcast app, it's from 2019. And the episode is called "How is But Why made? What is sound." But back to boats. What was that question that you all want the answer to?

Eliza 03:16
My name is Eliza. I am from Redwood City, California. I am seven. My question is how do birds flow?

Sunder 03:28
Hi, my name is Sunder. I am eight years old. I am from Seattle, Washington. But now I live in Melbourne Australia. Why does a stone sink but a huge ship or boat float?

Clara 03:46
My name is Clara and I am five I live in Carrabassett, Maine. Why do boats float even though they're so heavy?

Jackson 03:59
My name is Jackson. I am seven years old. I'm from Coquitlam, British Columbia, Canada. And my question is how do ferries float?

Ben 04:14
My name is Ben. I'm eight years old and I'm from Colleyville, Texas. My question is how do boats float?

Georgia 04:21
My name is Georgia and I'm six years old and I live in Waitsfield, Vermont. My question is why does the Boat Float?

Ernie 04:28
My name is Ernie. I am in Athens and I'm three. Why is a big boat so heavy and why can it still float?

Anna 04:42
Hi, my name is Anna. I'm six years old. I live in Toronto, part of Canada. And my question of the day is how do boats float?

Amal 04:55
Hi, my name is Amal and I'm eight years old and I'm from Toronto, Canada, and my question is, how do boats float?

Jane 05:05
So you're all asking a variation on the same question: how do boats float? Why does a stone sink, but a huge ship with lots of heavy cargo floats? Let's see if Fahad Mahmood can help us.

05:18
Sure, absolutely. So it has a lot to do with basically what's called the density of a material and the size of a material. So if you take a stone and you sort of feel the stone, that's, it will feel very heavy to you as you're holding it. That's because it's got a lot of mass, it's got a lot of matter, sort of packed into a very small volume. And so when you throw it, it sinks. Now a boat, even though it seems very large compared to a stone and should be much, much heavier, but it's also got a very large volume. And so when you put a boat on to water, it turns out that the overall density of that boat is actually not that high. And so in that sense, it allows it to float. What's actually happening on a much deeper level is whenever I place something in a water, if I submerge it, so if you've played in your bathtubs, you'll notice that they sort of, as you put some stuff in the water, the water level rises, right? If you jump into a swimming pool, there'll be a little rise in the level of the tub. And so what's happening is you or whatever object you're putting in the water is actually displacing that amount of water. And the amount of water that's displaced is actually going to exert an upward force on the object that's in the water. And so if that upward force is equal to the weight of the object, then the object would float. So it really matters how much water you are sort of displacing as you submerge it, a stone has a very small volume. And so it doesn't really displace that much water. But a ship is huge. And so as the ship goes in, the water level it sort of moves out of the way is very large. And that weight of the water, when it equals the weight of the ship, it can actually make the ship or the boat float. And if you actually look at most boats, when you-- they're actually very hollow, right? If you've been in a boat, it's actually mostly air in there, right? It's only the side that's solid, right? So the inside of a boat is mostly empty.

Jane 07:23
So if we took a boat and filled it with stuff, and removed all of that empty part of it, that empty air, it would sink, if we just took a canoe and put bricks and bricks and bricks in?

Fahad Mahmood 07:37
It would sink. It would exactly sink, yeah.

Jane 07:40
So you have to have a boat that is not so heavy that it just sinks. And it's not a matter of just being a heavy boat, but that there has to be--it's about how much volume the ship has, or the thing that's floating, versus how much water it can displace to sort of equal that.

08:01
Exactly, exactly. So if you want to have so if you want to carry a boat with those heavy bricks, you'll have to make a much larger boat. Because then it can sort of displace all of that water. And the larger amount of water it's displacing, the more force it's going to put up on the boat and the more weight you can put on.

Jane 08:17
And it doesn't matter how big the ocean is? Or, or like the if you could have a bathtub that was as big as a cargo ship and you put the ship into a bathtub, or you put the ship into the Pacific Ocean, it doesn't matter how much water there is, right? Either way it will float.

08:34
Right. Exactly. Exactly. And the ocean is pretty big, right? So the levels rise a little bit, but really not that much, right? Because it's huge.

Jane 08:41
Right. We're not seeing a new tide just because somebody put their boat in the water.

08:44
You're not seeing a new tide. Exactly, exactly right. So this this actually whole concept was discovered by Archimedes. So Archimedes, who was a Greek scientist, philosopher, he, you might have heard this story, but he was, he discovered that when he was bathing in his bathtub, and he would, when he jumped in, the water level would rise. And the tale as it goes, and no one knows if it's true or not, but essentially, someone in the ruling class had told him to test whether a piece of gold was (gold crown) was real gold, or it was a fake. And no one knew how to do it. And he sort of figured out that when he submerged the gold in water, it would make the water level rise and the level that would rise was equal to the weight of the gold. And from there, he could deduce whether it was real gold or not. And so that's that's when there's a famous thing where he jumped out of bathtub and he shouted, "Eureka!" right? So we all, whenever we discover something we were like, "Eureka!" That comes from Archimedes noticing that the water levels rise when you know when you are submerged in it.

Fahad Mahmood 08:46
So if all of the kids who are listening now suddenly shout Eureka when they're taking a bath, they can tell their adults this is why.

09:56
Yes. Yes, absolutely. Absolutely. So I would encourage you to do that. So.

Jane 10:01
One of the other questions is about cargo ships. And you know, we've been talking about this idea of displacement, that the the ship or the vessel displaces a certain amount of water and that has to equal the volume of the ship.

Nolan 10:16
Hello, my name is Nolan and I live in North Charleston, South Carolina. And I'm seven years old. My question is, how do big cargo ships float?

Asa 10:30
My name is Asa, and I am six. We live from Brooklyn. Why are container ships have lots of containers on them? Why do they not sink? Cause, why do they not sink?

Jane 10:48
Cargo ships get loaded up with a lot of stuff. Sometimes they carry all of the things you might buy in a store, maybe even cars and other things, and they go across the ocean with such heavy loads. Is there, so how can a ship that's four soccer fields long, full of heavy stuff, still float?

11:08
So that's an excellent question, Nolan, and it goes back to the same thing, which is: the cargo ships are huge. And most of the stuff in the cargo ships is actually also empty full of air. Especially if I look at the body of the ship, the sort of, the part--when you when you're looking at a cargo ship on floating on an ocean, you actually don't see what's underneath the ocean surface, right? If you look underneath the ocean surface, there's actually this large amount of boat, which is actually an empty hull. So inside, you'll have some machines, you'll have like the propeller and all of this stuff, but all around it is just air. And so again, the overall density of the ship comes out to be smaller than the density of the water. So that's how, again, cargo ships have to be huge. Because most of it is actually air.

Jane 11:54
Will in Richmond, Virginia wants to know just generally how things sink or float, not just boats.

12:01
And I'm four years old. And how do things sink and float?

Jane 12:05
So is it the same principle for everything that floats?

12:08
it's the same principle for everything that floats. And from a higher, sort of from a deeper level you can...the reason this works out very nicely is because of the pressure that water exerts on an object when it's sort of submerged in water or any sort of fluid or any liquid that you may have, if I put a solid object inside of a liquid, there's pressure acting on the top surface and pressure acting on the bottom surface. And that pressure, it turns out is related to how deep the object is. And so based on the height differences of the object, based on the height of the object, there is this net pressure being exerted on the object in sort of an upward way, which results in this upward force. And overall, it works out that, ultimately, it's just the density of the water that's or the liquid compared to the density of the object that will make it either sink or float.

Jane 13:12
Let's take a beat to make sure we all understand. So to figure out if something is going to float, a boat or anything else for that matter, you have to look at its density. That means how much mass it has, which is kind of like how heavy it is. And its volume, the amount of space it takes up. Here's an experiment you could do. Find a rock that can fit in your hand and gently drop it into a container of water, could be your bathtub, or a bucket or just a big bowl. That rock will probably sink. But now see if you can find a nice light container that's a fair bit bigger than the rock but not as big as your container of water. Maybe a plastic bowl or a snack container. Put the container in the water and see if the container

floats. Once you found a container that floats in your water, put your rock into the container. Does it still float? Try experimenting with different sized rocks and containers to see if you can get the rock in the container to float on the water.

Jane 14:15
The rock doesn't float on its own because it's too dense. It's both heavy and small. So it's more dense than the water it displaces. But when it's in the container, the weight of the rock is distributed throughout that whole container, which is a much bigger size. And the density of the container, which is basically a boat, is less than the density of the water. And now the whole thing floats. It's the same thing with very big container ships that carry lots and lots of heavy objects. If the ship is big enough to distribute all that weight, all that mass, it can still float. Speaking of which:

Evan 14:53
Hi, my name is Evan. And I'm four years old. I live in Kirkland, Washington. My question is what's in container ships?

Jane 15:03
That's a great question, Evan. If you live near or have visited a port where ships come in to the land, you may have seen big cargo ships. These very very big boats will be stacked high with colorful metal containers. Each of those containers is big enough to fit on the back of a tractor trailer truck. But what's inside? Well, the answer is: could be anything! Some of these container ships carry clothes, furniture, electronics, and toys. Some are called tanker ships, and they carry liquid things like chemicals, oil and gas. Other ships carry food, like fruits, vegetables, meat and fish. Some might carry big bulky things like rocks and grain. Others even carry cars and other vehicles. Globally, about 90% of the things that are traded between countries travel around by container ship. And these container or cargo ships are huge. The biggest one is 400 meters long. It would take you five minutes or more to walk from one end to another. That's big. Okay, now that we know how boats float, coming up, we'll learn about how they move.

Jane 16:15
This is But Why: A Podcast for Curious Kids, from Vermont Public. I'm Jane Lindholm. We've been learning about how boats float with Fahad Mahmood, a professor of physics at the University of Illinois, Urbana-Champaign. But boats like the big container ships we were just talking about don't just float, they actually have to get somewhere. How does that happen? Here's Mitchell.

Mitchell 16:38
I'm four years old. I live in air. Ontario, Canada. How do paddles make boats go through the water?

Naomi 16:47
My name is Naomi. I'm three years old. My question is how do boats move?

16:57
That depends on the type of boat, right? So if it is a sailboat, which is, you've seen, giant sails. And in the old days, we only had sailboats. They move by the force of the wind acting on this giant sail. And as

the wind sort of strikes that sail, you can sort of push the boat, it pushes the boat forward. You obviously probably have experienced under windy conditions, the wind is exerting some force on you. So that's how sailboats will work. And so then it it's a matter of sort of positioning your sail the right way to sort of catch the wind, right? The wind will push you forward.

Jane 17:37
And I'm thinking here too, you mentioned that kids have noticed this. So like, you could even try this as a kid. If it's a very windy day and you have a coat, open your coat and see if it makes you, makes the wind push you back more than when you close your coat. Because that it's almost like a sail and it can move your body.

17:54
Yep, exactly. The other cool thing to try was like try with an umbrella, right? Like, hold an umbrella and sort of push it, keep it with the wind going. And you'll see you'll be like, "Oh, okay, it's going forward." So.

Jane 18:05
So that's how sailboats work.

Fahad Mahmood 18:06
That's how sailboats would work. The other types of boats, if you see these cargo ships, they work by, there's actually a propeller underneath the water that you don't see. Those propellers are actually huge. They're like the size of like seven or eight-story buildings. Because for these big cargo ships. And they're basically these giant fans that spin. And if you have experience, you have fans at home, you know, the fans, when they turn, they're pushing air at you, right? If you make a fan go the other way they actually pull the air, right. So the way the boats are working is they're making this fan go and they're sort of pushing the water. And so as the water gets, you know as they're pushing against the water, the water then pushes the boat forward. Same thing that that airplanes work, basically, there's propellers in there that pull in the air and then push it out and the airplane goes forward. So that's how these big cargo ships work.

Jane 19:00
When you talk about a propeller, it's usually propellers are all the way underwater. But they're kind of like a lot of paddles in a circle. So it's constantly making a paddle motion. And when we think about using a paddle, we're, we're kind of doing the same thing. We're pushing through the water, which then creates resistance and moves the boat forward. But we're using our own body energy to be the force that moves the paddle, right?

19:26
That's right, we're using our energy. We're converting it into moving the paddles and the paddles are pushing the water back. And there's a famous, you might have heard there's a famous law, Newton's third law: every action has an equal and opposite reaction. So if I push the water back, the water's going to push me forward. That's the equal and opposite sort of action. And so that's how all of these

boats are working, right. The propellers are pushing the water back and the water is pushing the boat forward.

Announcement 19:59
[Honk] May I have your attention, please. During docking, stay off the stairs, ramps and landings until the ferry has come to a complete stop at the terminal. Thank you for writing the Staten Island ferry.

Jane 20:16
Well, that'll do it for this episode. Thank you so much to Professor Fahad Mahmood, of the University of Illinois Urbana-Champaign, for telling us how boats float. If you do some of those experiments we talked about with floating, will you share your results with us? You could have one of your adults or your teacher record your results and then you can tell us about what you learned. Send your videos to questions@butwhykids.org And maybe we'll feature you in our social media. That email address is also where you can send your questions: questions@butwhykids.org. We love hearing about anything you are wondering: history questions, culture, art, music, science, animals, friendship, big feelings, whatever you think we should do an episode on. Your adult can record you with a smartphone's memo function and then send the audio file to, you guessed it, questions@butwhykids.org. But Why is produced by Melody Bodette and me, Jane Lindholm, at Vermont Public and distributed by PRX. Our theme music is by Luke Reynolds. We'll be back in two weeks with an all new episode. Until then, stay curious!