MARK HARTMAN: Can we grab the straws, the long straws? I want your group to measure the length of one of these chalkboards-- well, not chalkboards, but whiteboards. Your challenge to start with is measure the width.

And again, this is linear width, like we're actually going to measure it with a ruler. I want you to measure how wide each of these whiteboards is using this unit. We are going to give you premade units. They may look like straws, but they're actually premade units.

So what I want you to do, so I want you to measure the width of each-- well, just pick one of these from one side to the other, and I want you to measure by counting out. And you can just put the straws right next to each other. I want you measure how wide each of those boards are.

Measuring linear width of a whiteboard. All right, so what did you guys have as your width measurement using long straws?

AUDIENCE: 12 and 1/2.

MARK HARTMAN: 12 and 1/2. So width equals 12.5 long straws. What was your width measurement in short straws?

AUDIENCE: 37.

MARK HARTMAN: 37. So width equals also 37 short straws. These are two observations. You made a measurement, which is measurements are observations. You could say that object is red-- that's an observation. But you could also say that object is 12 and 1/2 centimeters wide.

These are two observations. Somebody throw this out for me. Thank you. Don't like those.

I'm going to give you a model. Think of converting between units as using a model of how these two units relate to each other. I'm going to tell you that one long straw is equal to three short straws.

And again, this is my number and this is a unit. The unit is long straw, just like inches or centimeters. It just happens to be called a long straw.

And I'm telling you that for a fact we know that that's equal in length to three short straws. So this is my model. It tells me how those two quantities relate to each other.

I can use this model to make some predictions, right? We actually just observed this relationship, but we didn't have to go through and measure the 37 short straws if we had known this in the first place.

Let's check it out. Here's how I'm going to want you to do every factor label conversion, unit conversions-- we're going to do it in a way called factor label conversion. I'll tell you why. So if I said I wanted to start with my width equal to-- and you're going to do this all on one line, and then you're going to simplify on each line below. If I start with 12.5 short straws, now I'm going to multiply by a number that's equal to 1, because I don't want to change the actual quantity that I'm working with, I just want to change the units.

AUDIENCE: So you multiply by 3, right? Multiply 12.5 by 3?

MARK HARTMAN: You could multiply 12.5 by 3, and that gets you to about 37, right? But that's not how we're going to do it. We want you to not just multiply numbers. Numbers don't mean anything.

I'm going to say that once, and I want you to listen to it forever. Because anytime you're talking about a quantity, the number and the units are equally important. So any time you write down a number, if you don't write down units, I will yell at you, these guys will yell at you, we will call you out. Because in science, there's no such thing as just a plain number. If there is, we'll tell you.

So I'm going to multiply by a fraction that is equal to 1. This is a quantity. I want to multiply by a fraction that is equal to 1, and I want to obtain a unit. I want to obtain the same quantity in units of-- oops, that's not 12.5 short straws-- 12.5 long straws. And I want to end up with short straws.

So think about it in this way-- if it helps you, you can make each one of these factors a fraction. You can say 12.5 long straws divided by 1 times-- let me move my times down to the middle. I want to be able to cancel out long straws on the top and the bottom. And I want my answer to be in short straws.

If I know that this number, this quantity, is equal to that quantity, I can make two fractions that are equal to 1. I can say-- again, this is our model-- I could say one long straw over three short straws, that fraction is equal to the number 1. Because this quantity is the same as that quantity.

The numbers are different, but the number and the unit together, one long straw, that's a physical measurement, that's the same thing as three short straws. I can also say that one is also equal to three short straws over one long straw.

That's like saying this is still the same quantity. Three short straws, bing bang boom. One long straw, bang. Still the same quantity. So the same quantity divided by the same quantity, these are all equal to 1.

So I'm not changing what I'm working with over here, I'm just changing the units. So I can choose. Do I want to multiply that number by a fraction that represents 1? Do I multiply by this one or do I multiply by that one?

If I want short straws to come out on top, we're going to want to use this fraction. Again, I'm going to throw that out.

So I want to say three short straws-- I want you guys to write this down-- over one long straw. So I follow my work over. I've got long straws divided by 1. That's just to make it look like a fraction.

Let's write the whole thing out. If you multiply two fractions, you write the top times the top. So 12.5 long straws times three short straws, divided by 1, times long one long straw.

All I did was I multiplied the tops together, put them together. Multiply the bottoms together, put them together. Make sense?

Now I'm going to simplify down below. And when I simplify, I always just want to keep my equal signs in the same place. And I just want to simplify this expression. When you're dealing with units, units work the same way that numbers do. You can cancel if you have 12.5 long straws on top and so many long straws on the bottom.

I can cancel out long straws, and I'm left with-- what is 12.5 times 3?

AUDIENCE: 37.

MARK HARTMAN: 37 short straws over-- 1 times 1 is 1. So that gives me 37 short straws. That makes sense with our observation. That if we measured, if we actually physically measure them, this makes sense.