

Hi everyone, welcome to Dimensions of Mass and Force.

As we've discussed previously, mass is one of the seven fundamental or primary dimensions and all other variables are made up of combinations of these fundamental dimensions so for instance force for example, force is a secondary dimension that is comprised of a mass times a length per unit time squared. So, as you can see, mass and force are really different dimensionally, but it is kind of common that people will confuse them. The dimensionality of force is given by the application of Newton's second law which tells us that a force is equal to a mass times an acceleration so if I replace the variables with their dimensions then I'm going to wind up with the dimension of mass, multiplied by the dimensions of acceleration which is a length per unit time squared and that's what gives us the dimensionality of force. So, one application of Newton's second law that you guys are all familiar with W equals mg . So, this happens when we apply a specific type of acceleration, gravitational acceleration given by g , um to derive a specific type of force which would be weight.

So, let's talk about the units of forces in SI units and in US customary units. So in SI units, um first I want to say that it doesn't matter if you're working in SI or unit US customary unit systems uh the derivation of dimensionality of force is always the same, right it's always given by that same oops that same application of Newton's second law. Right so that's the dimensionality of force has nothing to do with the unit system but when we apply F equals ma in SI units the mass for instance would be something like kilograms and then our gravitational acceleration constant would be given in meters per second squared and so we wind up with units of force in Newtons, N. And so then if we wanted to convert we would use a conversion of 1 Newton is equal to 1 kilogram times a meter per second squared and our unit conversion ratio would then be that 1 Newton divided by 1 kilogram times a meter per second square equals 1 there's our unit conversion in SI. Okay so in units of US customary again we're applying that same F equals ma so this time our mass might be in pounds of mass and our gravitational acceleration might be in feet per second squared and our units of force rather than Newtons are going to be given in pounds of force. So, one pound of force is equal to 32.2 pounds of mass times feet per second squared and so our unit conversion ratio becomes 1 pound of force divided by 32.2 pounds mass times feet per second squared is equal to 1. So, this is where some mistakes are made because there's a different conversion ratio in SI and customary units. In SI units we have this 1 to 1 conversion ratio right, 1 Newton is equal to 1-kilogram times a meter per second squared. Um in US our ratio isn't 1 to 1, it's 1 to 32.2, one pound of force is equal to 32.2 pounds

mass times feet per second squared. And sometimes we forget to apply that different conversion factor when we're working in the US customary units we get so used to working in SI with a 1 to 1 that we forget to actually add that conversion ratio and then we report a final answer in units of force that is off by a factor of 32.2, which of course we want to avoid.

So, let's look at an example. So, suppose I want to determine the weight of a substance that is on Earth and to accomplish this I use a mass balance, or what we would commonly call a scale. Um and let's say that my scale has dual unit system so it can measure in either SI or customary units. So, I would first set the units of my scale to measure uh mass in kilograms. So, I mass my substance and my mass balance tells me that mass is equal to 25 kilograms and then I reset the units of my scale to measure in pounds of mass and I find that that same substance has a mass of 55 pounds of mass in US customary units. And so I'm going to convert my mass um into its weight and so for both I'm going to use that application of Newton second law, that weight is equal to a mass times the gravitational acceleration since we're on Earth will be using the gravitational acceleration of the Earth's surface. Um and so for example in my SI measurements I'm going to apply that 25 kilograms of mass times my gravitational constant of 9.81 meters per second squared and I get 245.25 kilograms times meters per second squared. And now I'm going to apply my conversion ratio of 1 Newton being equal to 1-kilogram times a meter per second squared and I wind up with 245.25 Newtons. So that is the weight of my 25-kilo mass. So now I am going to do the same thing but using my mass in pounds of mass. So again my weight is going to be equal to mass times acceleration just the same way this time I'm working with 55 pounds of mass as my mass and this time my gravitational constant will be 32.2 feet per second squared and this is going to give me 1,771 pounds of mass times feet per second squared. So now I'm going to apply my conversion ratio, this time my ratio is 1 pound of force to 32.2 pounds of mass times feet per second squared. Right so my pounds of mass and feet per seconds squared are going to cancel and this is going to leave me with a value of 55 pounds of force so this is my weight of the subject in um US customary units, my units are pounds of force but look at that the value of 55 pounds of force the number is the same whether we're looking at the mass or the force, and this is true the value of mass and force is going to be the same for any substance on the Earth's surface that's being measured in US customary units. So this is probably one of the reasons that we sometimes confuse weight and mass because you'll notice that the value of mass and weight in SI units is different so another thing that could be adding to our confusion is just the fact that in SI we use different words for units of mass and force. Right for mass we use kilograms in the unit for force we use the word Newton, and this makes it very clear that the two things are different. When we're talking about US customary units again, we use the same word

pounds to describe both mass and force. So it's really important for us to pay attention to is the pound a pound of mass or a pound of force so we designate that by either writing a little m after pounds mass or a little force a little f down here after our pounds of force, and that helps us to remember which pound is a pound of mass and which pound is a measure of weight or force.

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Good job reaching the end of this video please reward yourself with a moment of Zen. I study fluid mechanics because I love water and healthy aquatic ecosystems. Whatever your passion is I hope it motivates you to continue your study of fluid mechanics