Hi and welcome to Engineering Earth. The topic of today's video is a brief review of systems and control volumes.

In chapter one you studied an overview of basic definitions for systems and control volumes, which we then applied to derive the Reynolds transport theorem, at the end of chapter 4. Before we move forward and apply the Reynolds transport theorem to analyze mass energy and momentum fluxes, we're going to recap these definitions and consider a couple of examples. Systems are defined as a quantity of matter. So, let's say that I'm interested in analyzing this quantity of matter shown in this shape right here. All of the mass within this shape that I've drawn is my system of mass and mass that is not in my system is known as the surroundings. And the surroundings are separated from my system of mass by this boundary. The properties of this boundary are flexible: it can be a physical or an imaginary boundary, it can be fixed in space, or it can be able to move or deform, or move and deform at the same time. If the amount of mass that is in my system is fixed and no mass can cross the boundary, then my system is said to be a closed system. Right, so if I've got mass trying to cross between my surroundings in my system and it's unable to cross then that makes this a closed system of mass, which is sometimes also called a control mass. In most closed systems, energy can pass through the boundary, so it can go from the surroundings into the system of mass or can cross from the system of mass out into the surroundings. Whereas, as we discussed earlier, mass cannot cross my system boundary, can't go from outside of the system into the surroundings, it gets blocked by the boundary, whereas energy can go both ways. Um I say that in most closed systems the energy passes through the boundary, there are some that do not allow energy to pass, and these are a specialized case of a closed system known as an isolated system. We won't be studying these too much in detail.

So, I'm going to give you an example of a closed system of mass. So, in this system we have got an airtight tank, and it contains 1 kilogram of some sort of a gas contained within a space that is of a volume of 1 meter cubed. So, let's say it's like a rectangular tank with a volume of 1 M, and this system is closed it's airtight. So, I'm going to show you the boundary of my system of mass it's coinciding with my physical tank walls in this case, but this red dashed line is my boundary that separates my surroundings from my system of mass. Now I'm going to apply some heat down to the bottom of my tank, like this. And since this is a closed system, but not an isolated system, that energy is going to be able to pass from the surroundings into my tank and heat up the matter that's within the tank. So, the mass can't cross the boundary of this system, but since the energy can, the gas that is in my system is going to change its temperature. As the temperature goes up the gas is going to want to expand its volume, but since the volume contains, meaning this mass has been fixed by these physical immovable boundaries, the mass cannot expand. So instead what we're going to see is an increase of pressure in this gas against the tank walls. So now let's consider the same system. So again, I've got my physical uh boundaries of the tank I've got my one kilogram of the same gas occupying 1 cubic meter, but I'm going to make one small change in this example. Instead of all of my boundaries being fixed, I'm going to imagine that one of my boundaries is movable. So, it's like a piston that's able to move up and down. So, initially my system boundaries are these physical tank walls, just like before. And initially I've got this volume of 1 cubic meter containing my 1 kilogram of mass. And so now I'm going to apply my heat, once again my energy is going to cross my system boundary from the surroundings into my system of mass, and once again my air within the tank, my gas within the tank is going to want to expand in uh response to that temperature increase. And now this time what's going to happen is instead of being contained within the same volume, my piston is going to rise. So that increase in pressure against the tank wall is going to cause my piston to go up to a new position. And now the boundary of my system is going to expand with that change in the piston's position. So, my new system boundary is going to look like this and now my volume is no longer 1 cubic meter, it's going to be greater let's say it expands to two cubic meters like this. Both of these examples that I've given are examples of closed systems. The different behavior that we observe is only happening because one of the closed systems has a fixed boundary over here and the other one over here has a movable boundary. But they are both closed systems, in neither example has any mass crossed over that red dash line. In my second example, the red dashed line expanded to accommodate the expansion of my system of mass in space.

So here is another example of a closed system of mass. In this example we're looking at water flowing in a river channel. So up here is my free surface, surface of the river, down here is my river channel bed, and my water is flowing from left to right in my river channel. So, we're kind of looking at it from the side in a longitudinal profile. And I am going to consider a system of mass that's occupying a space within my river channel. So, in this case my system of mass is 1,000 kilograms of water within my river. And in this case, my boundary of the system of mass is not physical, this red dashed line is just an imaginary line that I've drawn that separates the water in my system from the water in the surroundings, so for instance from the water that's directly upstream. And so I'm going to start a stopwatch and at the time that I start my stopwatch is time zero and my system of mass is, as I've drawn it, in this position right now and then some time is going to go on and my system of mass is going to flow downstream as the river flows, such that after some time, t, has elapsed, my system of mass has moved from upstream to downstream. Now, this is the same mass right, the mass of my system at time t is 1,000 kilograms, just like it was at time t equals 0. And that's because it is in fact the exact same mass, it's the, it's literally the same molecules, they've just moved from upstream to downstream. So once again this is a closed system, and no mass has crossed this red boundary either going in or coming out, so my system always has the same mass. Um and in this closed system example all of the system boundaries of my system were movable.

So now, let's contrast closed systems with open systems. An open system of mass is one where both mass and energy can flow into and out of a select region in space that we call a control volume. So once again, I'm starting kind of with an um an amount of mass and it's separated everything that's inside of my control volume is separated by everything that is outside of my control volume by this red dashed line, similar to the boundary of my system of mass. My boundary of the control volume we call the control surface. Okay, so how is a control volume different from a system of mass, a closed system of mass that we've looked at before? An open system of mass is one where both the mass and energy flows into and out of the control volume. So, before I couldn't have any mass crossing my system boundary and this time, I can have mass fluxing across my control surface to leave the control volume or coming in from the surroundings. Same kind of thing with energy, I can have energy coming into my control volume and leaving. So, analyzing fluid flow problems using a control volume approach takes the emphasis off of the mass system itself, and instead focuses our energy on characterizing the fluxes of mass energy, or momentum, that are happening through the control surface boundary. So, we want to, we want to characterize, well, how much mass has come into my control volume, how much mass has left, and what's the difference between how much has come in and gone out. Because that's going to tell us about how much mass has been stored within our control volume. In open systems um our control surface that is similar to the boundary of systems of masses um again it can be physical or imaginary, it can be fixed at one point in space, or it can move, or deform, or do both at the same time.

So I like to envision control volumes um as a bathtub. So, let's imagine that I have a bathtub, it'll look something like this. So, my bathtub has a drain in the bottom and water comes into my tub through a faucet, so water's coming in here and it can leave through this drain like right here. And so, if I consider the bathtub as my control volume, I can think about my control surface separating out everything that's inside of my control volume from everything that is outside. And so, in this case my control surface is a hard, physical boundary of the tub walls itself, but then there's an imaginary boundary as well that's happening over my drain in the bottom and over the opening in the top, where the water comes in. So, if I have more mass coming in through the faucet than I have mass leaving in the bottom through the drain over some period of time, let's think about what's going to happen to the amount of mass within my bathtub. So, this is my water level in the bathtub and let's say that so I'm running both the faucet, and I have the drain open at the same time, and my faucet is bringing more mass into my tub than is draining out through the drain what's going to happen? Well, the water level in my tub is going to grow up right. We've all had this experience of filling up a basin or a bathtub before. And so, this increase in mass over that time that I'm filling this represents, you know, the storage of mass within my control volume over that time. And the same thing would be true if I had more mass leaving through the drain than coming in. Let's say it's the end of the tub I have turned off the faucet, there's no more mass coming in and I want to drain all of the water out of my tub. Then the water level is going to go down and so over that time I'm draining the tub I'm going to have what you could think of as a negative storage, a decrease in the storage of water within my uh bathtub control volume.

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Excellent job reaching the end of this video and 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.