MARKUS KLUTE: Welcome back to 8.20, special relativity. In this video, we talk about Galilean transformation. So what is it you're going to do? We want to describe our event P, maybe Professor Klute exploding, with two different reference frames.

We can call one of the reference frames our laboratory frame. Maybe that's the frame in which Professor Klute was stationary. It has an origin and has axis x, y, and z.

And then we have a moving frame, which is moving with a constant velocity with respect to the laboratory frame. The origin is o prime. The axes are x prime, y prime, and z prime.

All right, so now what do we learn from this? Let's think about an example. An example most of you have experienced before is the one where you sit in a train car. And, if it's not a train car, it can be a car or a plane, something which is moving with respect to Earth.

If you look out of the window and the acceleration is very, very minor, it's often not clear whether or not the Earth, the train station, or the train car is moving. And so you have this kind of weird feeling that, you know, I don't know if maybe the neighboring train started moving or I'm moving.

But what we're going to do here is describe you sitting in the train car, reading a newspaper, once within your laboratory frame, within the frame of the train, and then we want to describe the very same events or sequence of events in the frame of the stationary train station.

All right, let's look at a specific example. Here again our professor is exploding at a time tP at xP, yP, and zP. To make this a little bit easier, we define, at time t equals 0, the origin of the two frames coincide. That just means that, at the origin, we have two clocks, two watches. And we make sure that they're synchronized.

And then my watch stays with me, and then the second watch may be with you, which moves along. And those are great watches. They are synchronized.

We also want to simplify-- we can always define the direction of our coordinate system such that the velocity, the relative velocity between the two reference frames, is in one specific direction. And here I decided to use x. I could have used y and z, and I could rotate the coordinate systems or the relative movement of the coordinate systems in any way. It's just a simplification here.

When I do that, I can rewrite this event P in the S prime frame through the S frame in the following way. So, for x, we find that xP is given by-- x prime P is given by xP minus v, the velocity, relative velocity-- I could put a little label x here-- times tP. And then, for the y-coordinates and the z-coordinates, there's no change. For the time, intuitively, you say that those two watches are run with the same speed, meaning that the time in both frames for the same events are the same.

So now I'm asking you, if you're watching this video, to find the velocity and the acceleration. It might be good to stop and just write this down. So find the velocity and acceleration of S prime, of S prime expressed by the S-coordinates. So let's try to do that.

So, first, we build the derivative dx prime dt prime, which is our velocity. That's the velocity of an object in my prime frame. And that's given by d dt-- I can just do that here because the times are the same-- times x minus vt. That's [? x, ?] ux, the velocity in my S frame, minus v. That's really what you expect. You just subtract or add the velocities.

If I then build the acceleration, I have to build the derivative of u x prime, which is our acceleration, in the prime frame. Here again I just do this in x-direction because the solution for the y-direction and z-direction are trivial. So now I find d ux dt minus dv dt.

Now, the velocity, as we defined, between the two reference frames is constant. Therefore, this is 0, meaning that the velocity-- the accelerations in the two frames are the same. If the accelerations are the same, that means that the forces in the two frames are the same. And that means that the forces or the accelerations are invariant. They do not change based on the reference frame that I use.

So now, coming back to the example we discussed in our very first lecture, you are experiment in the train car. S, the velocity between those two frames, the frame in your car or a second frame, are constant. There's no way to tell whether or not your train car is moving or not. That is only true as long as the velocities are constant and unchanged, constant.

So, in summary, in Newton's mechanics, time and accelerations are invariant and, therefore, also the forces. There is no inertial frame which is above another one. So you can pick one or can pick another one. There's no difference in the descriptions of the physics between those two frames.