Introduction to Soft Matter

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Lecture No 06

Creep and stress relaxation

Welcome again to this course on Introduction to Soft Matter. We were discussing last time two behaviors, two important phenomena that we had discovered which is the Creep phenomena and the Stress Relaxation phenomena. So, let us just quickly go back to that.

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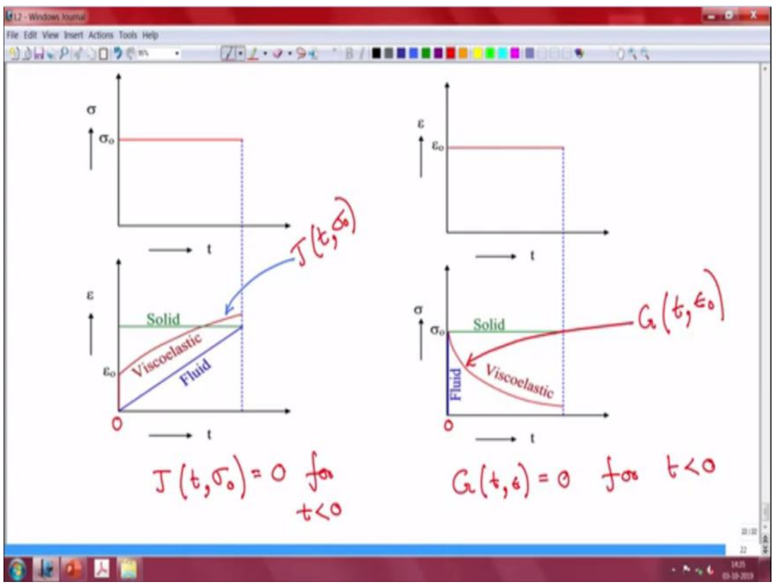

So, what we had seen and this is a combined graph of all of them, all the three important behaviors that we had discussed. So, we show, we found that when you apply a known amount of stress to a system the three, the two classical materials the solid and the classical (whisk) fluid, they behave differently and the viscoelastic response is somewhere in between the two.

And we had said that this particular curve, we are going to denote this as J T comma sigma. So, the creep function is a function of two important variables time and the stress applied here you can even write it a sigma naught, in general terms you can write it sigma.

So, this is a Creep and the next one the stress relaxation phenomena, we introduced ourselves to one more to the other phenomena which where we said we are applying unknown amount of strain and then stress decreases over time. So, this curve was given the name G or was denoted as

G T comma epsilon. So, once again, it shows you that it is a function of two very important variables time and the known amount of strain imposed.

So, we are going to look at this in a little bit of more detail, there is one more thing. So, for to make sure the system is so, the strain here is being applied at time t equals 0. So, what we are going to do is we are going to define those functions such that we know that this function is equal to 0 for t less than 0.

So, this function becomes well defined. And similarly, for the other case, we are going to say that or impose the condition that this function be 0 for times less than 0 assuming that obviously all the experiments are beginning it 0, so, this is the origin. So, then we have a continuous function that we will be able to integrate and perform other important calculations with.

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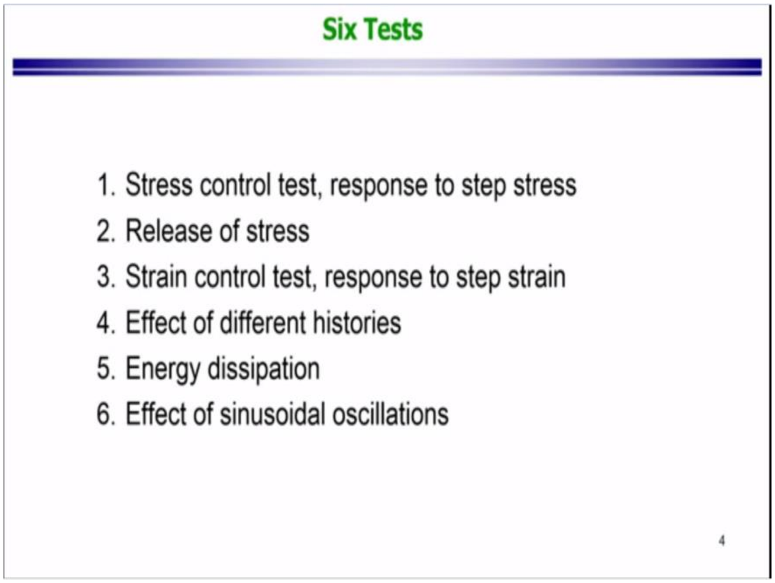

So, what we had started off with were these different tests, we have finished of the first discussion of the first three, and now, we want to discuss the fourth one which is a (differ) effect of different histories. So, let us do that.

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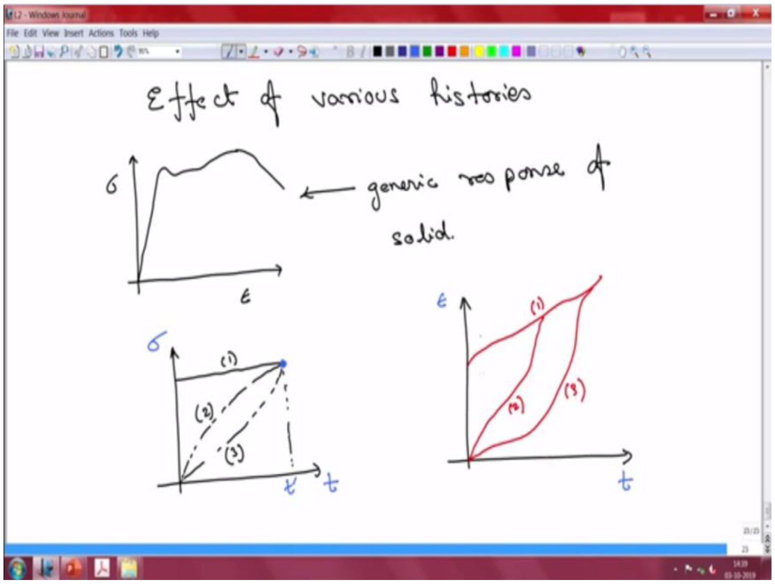

So, here we want to now have a discussion on Effect Various Histories. Before we do that, let us have a just quick recap of what we have for elastic solid. We did a number of different Strain, control and the Stress control tests and what we found out that the generic graph, if you were to plot, the Stress versus Strain looks something like this, where you have a initial portion and then, now this graph does not depend on the history by which you arrived at this situation.

Which means it does not matter how you did the experiment or how you imposed, what values or stresses that you choose, or what values of the, in a Strain control test, what values or strain that you chose, you will always end up with this graph. But that does not happen anymore for viscoelastic fluid or viscoelastic material.

So, this was your just a generic response of a solid body. So, now, let us if we want to try and understand that what we should do is let us have a condition where you are applying a known amount of stress, this is time, this is time, this is stress, this function ends here and then you have you can either do it this way or you go through a different path, different paths to arrive there. So, let us call this path 1, this is part 2, this is part 3.

What we see when we do these experiments is we are going to be recording a strain with time here. And what you see is that in this case, so, let us say this is the response to path 1, the response to path 2 can end up at a different location. And here, your path 3 can end up at a different location altogether. Please note the consequence of this graph. This is let us say you get it from an experiment.

So, here at a certain time, where you have ended or some t dash all the three experiments or the three paths have the same stress. But on this curve, you do not have that you will end up with different values of strain at these different times.

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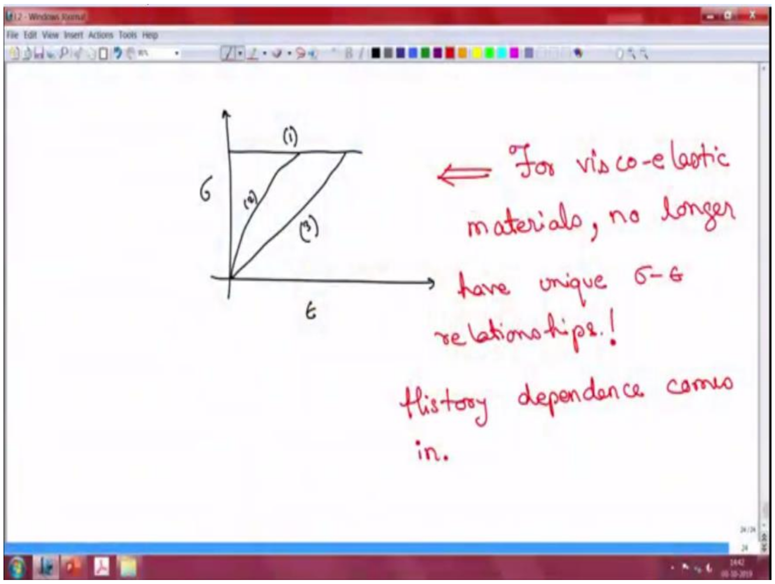

So, when you create a merged, when you create a graph of stress versus strain, what you find is the responses are no longer unique in the first path you will this will be, this is what it might look like, the second path and then this is the third path. So, for viscoelastic materials, you no longer have unique sigma epsilon relationships. And this is where history dependence comes in.

So, for you to know the response state of a viscoelastic material, you must know now, the path by which it had come there because it is no longer enough for you to (provi), for anybody else to provide an instantaneous value and then demand an instant, the value of the instant, of the response at that time, because the response at that at time t depends on the previous states.

And if you remember in one of the first lectures we were discussing how time becomes an explicit parameter, but for classical viscous solids and classical elastic (meta) solids, sorry, classical viscous fluids and classical elastic solids. Though time is an important parameter. And that is how you are conducting the experiment.

It hide somewhere although should have been a parameter that was there, but the time variable disappears, because you are only relating instantaneous response to the instantaneous value of the stress, but no longer even that will be true and this is exactly where the history becomes, history dependence becomes important. So, this is where viscoelastic deviates strongly from your what you might have studied in classical viscous fluid, fluid mechanics and solid mechanics.

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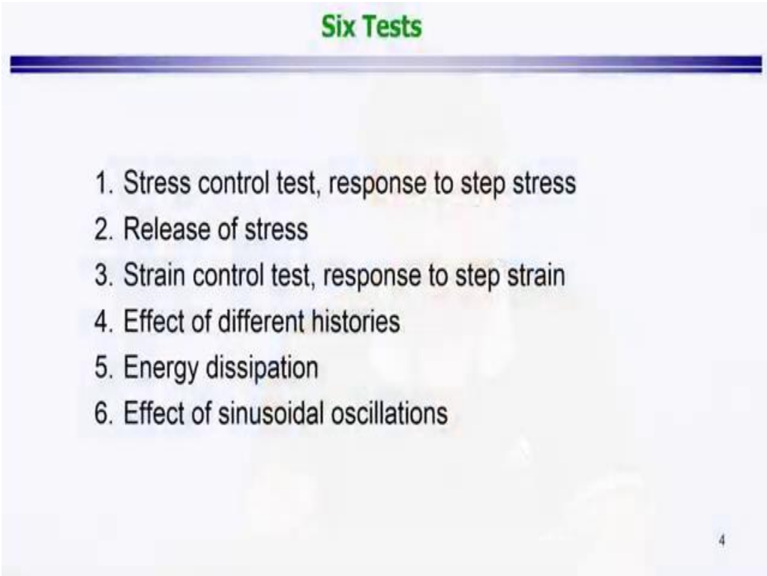

Okay, so, we have discussed four tests that leaves us with energy dissipation and effect of sinusoidal oscillations.

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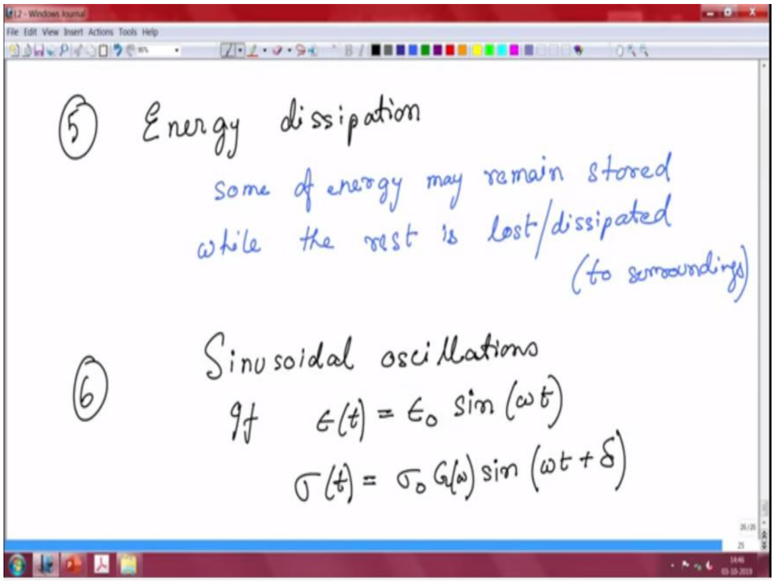

So, since we have always be discussing, so let us, this is the fifth test we will quickly discuss that. So, Energy Dissipation. Now, the moment we say energy dissipation we have to recall what we had said for the two other classical cases, in the case of the solid body, all of the energy is stored, whereas, for the fluid all of it is lost.

But here obviously, now that we have started to realize that this is somewhere in between, the response will also be somewhere in between. So, some of the energy may remain stored while the rest is lost or dissipated, dissipated to were? To the surroundings are within itself, dissipated as heat.

Brings us to the sixth and the final test, Sinusoidal Oscillations. So, if you apply epsilon equal to, let me this, epsilon, if you make an experiment the strain a function of time, a sinusoidal function of time and then you measure the state of stress. This now will have an amplitude and I will write both of them in a second. So, I will first write the sin portion, rather the sinusoidal varying portion.

We had seen that for elastic body, the two are supposed to remain in face, whereas for a viscous fluid, there is going to be pi by 2 difference, but now you are not going to have that, instead you are going to have some other difference where delta is not pi by 2 it is some other value. And here in the numerator, sorry, in the amplitude part you are again going to have a constant part and something else that depends upon omega the imposed frequency.

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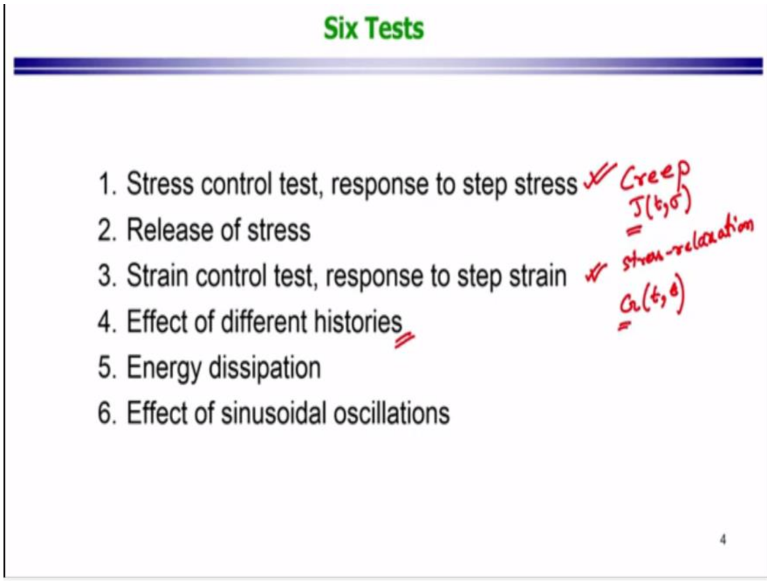

So, out of these six tests in our in that in our course we will see that the first one is very important because this give rise to the phenomena of creep and we realized that that we have to understand. So, associated with that we gave this symbol or the function J and then the strain control test is also very important because this is your stress relaxation. This gave rise to that phenomena.

The other three are also very important. We will see how this plays a role at a slightly later stage. And for this particular introductory course, we will not worry too much about test 5 and 6. But what were they are also very important in a more advanced course you learn in more detail, but for the sake of this particular course, will be focusing on these two important phenomena.

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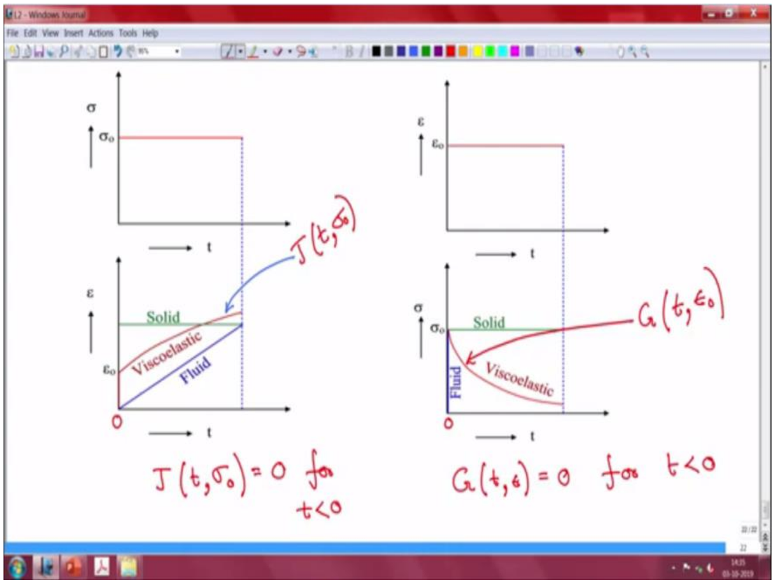

So, before we go into a little bit more depth about this we will just quickly come back to the Stress of relaxation phenomena because this also illustrate an important point and that is now, g so I can do I can create an artificial modulus.

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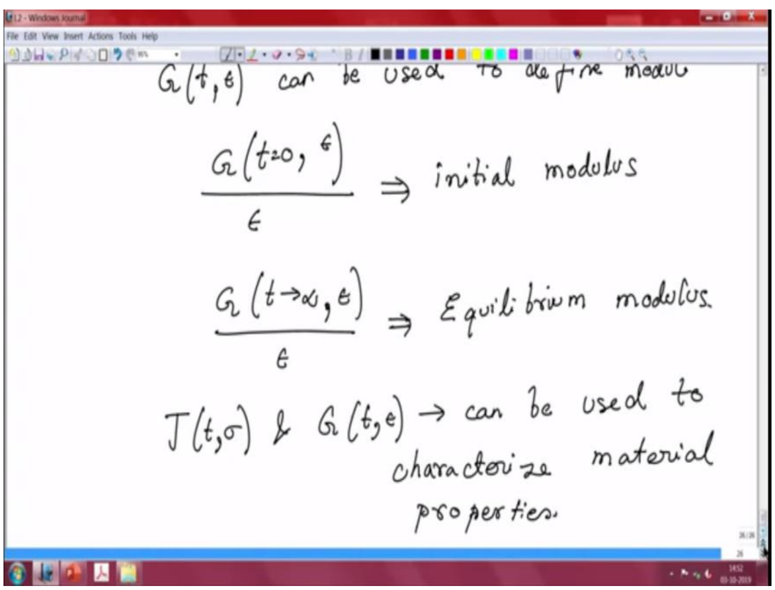

So, this function g can be used to define moduli. The various, and in Polymer engineering, a lot of people use the function g at t equal to 0 given epsilon divided by epsilon. And this is also called the initial modulus. Or you can even define another modulus where this t is tending to infinity. And this is also called equilibrium modulus. So, some people use this and quite a bit.

For example, in Polymer engineering, they use this and the important point here. So, we will do this in a little bit more rigorous fashion in a second. But the important point is that these two moduli can be different by even orders of magnitude. So, unlike the case of this the classic elastic solid where you can attach one modulus and that one modulus is enough to define the behavior of the material that is no longer going to be true.

So, you are having the modulus itself is now a function of time. The purpose of this was to illustrate the fact that this j t comma sigma and g t comma epsilon can be used to characterize material properties, material properties.

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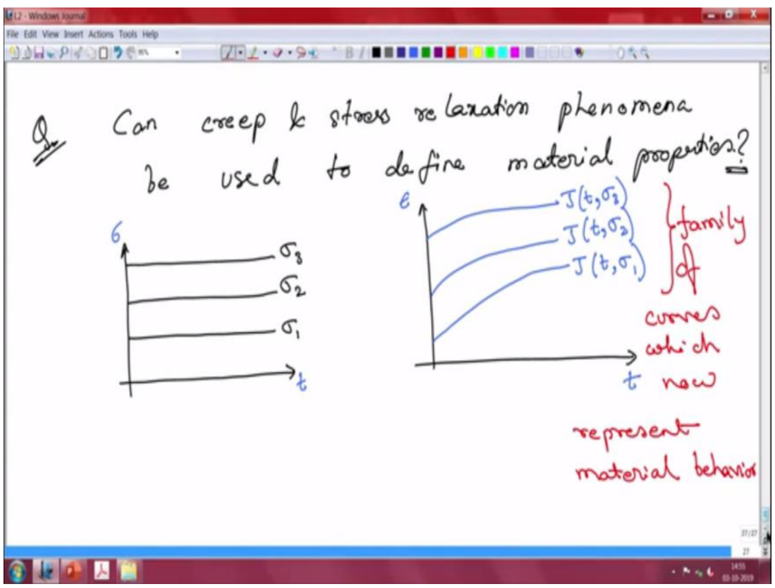

So, basically the Creep and the Stress relaxation tests can be used. So, the question that we want to ask is so, the question we have a question right now and the question is can Creep and Stress relaxation phenomena be used to define material properties and this is our question. So, we are going to look into this and lot of detail now.

So, let us consider, let us say that you are now visiting the lab. Okay. You have gone into the lab and you are the first test you want to do because you have learned that there is a list of tests and the first test you are saying that what I will do is I will impose a known amount of stress to the system, and I will see what the response is.

But what amount of stress? If you go, you might decide on one value. So, let us say student 1 goes, he decides on a value of sigma 1, he does the experiment with that. Then we send somebody else that person goes, he does the experiment again, but this time he chooses arbitrarily some other value. So, a third student goes, and he decides to conduct the experiment at a third different level of stress.

So, if you had to put together all the results, what we will see is so the three people will see three different graphs. So, the first person records J T comma sigma one, meticulously records this. The second person has meticulously recorded the response at the other level of stress, and so as the third person. Now, all of these graphs actually represent material properties. They are representative of the material behavior.

So, now you have all a family of curves which now represent material behavior. But what happens, so this other stress relaxation test the creep test, what happens for the other test?

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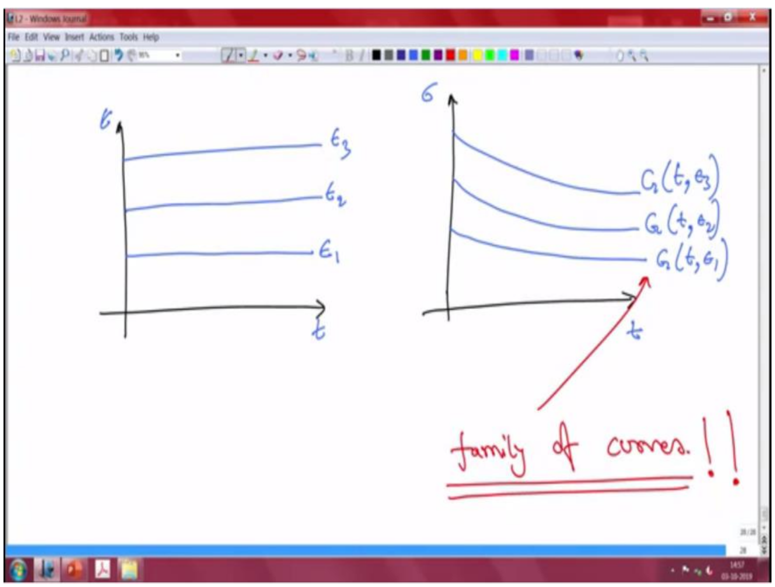

If you were, if somebody went and if a set of students decided to do the stress relaxation test instead at one of the days are they at the lab, then what would they find? They would apply sorry, this is strain, should apply to strain. So, the first guy goes, does an experiment imposes one amount of strain epsilon 1. So, he gets a corresponding graph. We will call this G T comma epsilon 1.

The second guy goes and he chooses a different value. And again, he gets a different curve. So, does a third person. So, now once again, in the stress relaxation experiment, you once again end up with the family of curves. So, this is a problem. Well, I mean, it is not so really a problem, maybe a material is so complicated that you cannot define it with one more graph anymore.

Like you are able to do in the case of the stress to incur for a solid mild steel for example, but here you have a set of curves. So, you cannot get away with it. But there will be some perhaps there is some condition under which you can simplify this. So, it does turn out that there is a condition which is called the linearity of scaling under which you can make some simplifications.

And we will see that in the next class, how linearity of scaling helps us define material properties from the creep relaxation test, and the creep tests and the stress relaxation test. So, yeah we will end this class here.