Introduction to Soft Matter
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Lecture 01
Introduction

Welcome everybody, welcome to the introductory class on the course which is titled Introduction to Soft Matter. So, this is a introductory lecture on introductory course. So, in this intro to an intro what we would want to discuss is what do we even understand by this terms soft matter, over the course of this, over the entire course of this series of lectures we will hopefully understand in great mathematical depth what we mean by the this topic, by this term called soft materials and other related terms. So, what we want to do today in our today's lecture, we want to focus on.

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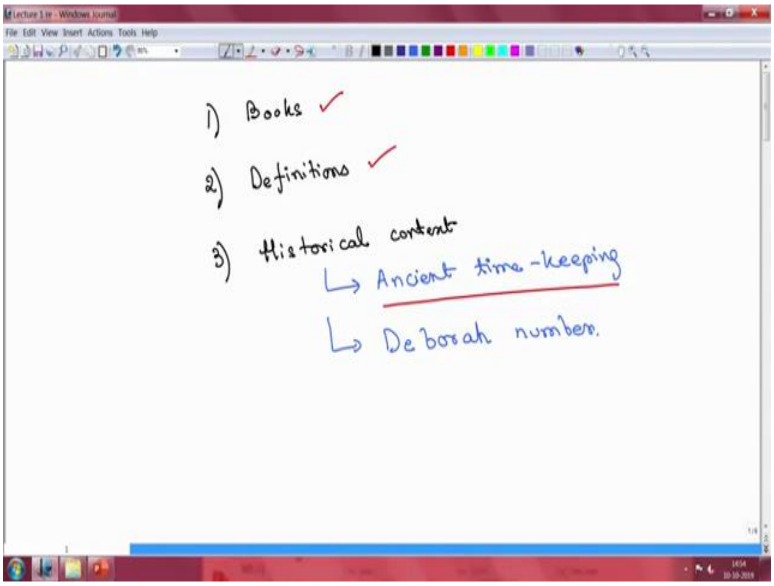

So, today what we are going to learn about reference texts for this, second we will make an acquaintance with some of the definitions of key terms and then third is I would like to look at historical context for this course where in the first part I would like to look at some of the work that was or some of the very interesting developments that to place in Ancient time keeping and that will bring us to an important number that we will be using throughout this course and that number is called the Deborah number. So, let us get started with the first part which is books (())(02:27).

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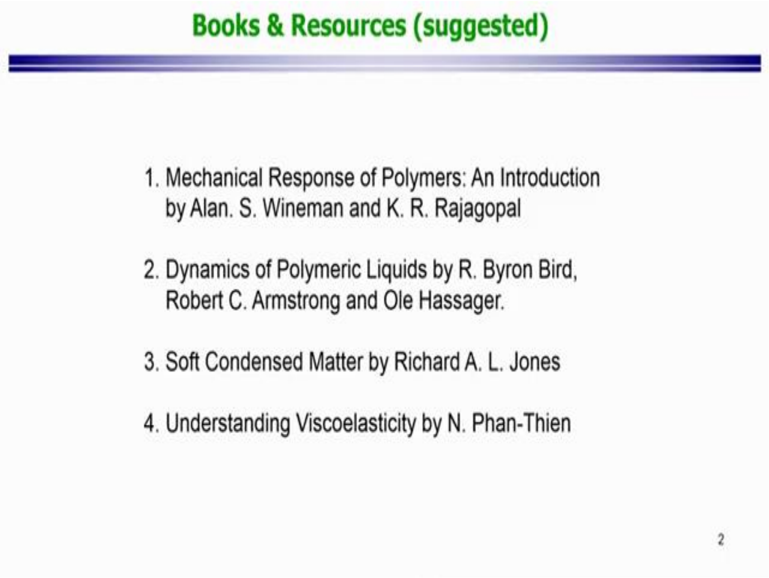

Now, it is how happen so, there are many different books, there are really good, there can be really good text books, the issue with soft matter is that this is truly and interdisciplinary course where a lot of different disciplines for example, chemistry, physics, mechanical engineering, aerospace engineering, chemical engineering all these come together. And as a result what has happened is there are many books which are written by authors keeping in mind, these different disciplines and hence, there are a variety of books of with the variety of different approaches.

So, I am not trying to detail all the different possible books that are out there. But, I have only made a small list from the possible different possibilities so, to my apologies to all the different books that I have left out because, there are certainly many good texts that I am not been able to refer here. The first text that is a suggested text here is called the title of the book is Mechanical Response of Polymers: An introduction and this is by authors Alan S. Wineman and K. R. Rajagopal, we will be using, we will be referring to this text quite a bit in this course.

Another is, Dynamics of Polymeric Liquids by there are three authors for this text book, which are R. Byron Bird, Robert Armstrong and Ole Hassager. This is also a very good text book and it is written quite a bit from the fluid mechanics prospective and we will also be referring to some parts of this book in this course.

The other suggested book here is the Soft Condensed Matter by Richard A. L. Jones and finally, this one more text that is Understanding Viscoelasticity by N. Phan-Thien. Okay, so these are suggested text books but we will, this series of lectures is designed to be more or less self-content so, the lectures are more or less sufficient for an introductory course on soft materials. So, those were the books now, we had said that we do want to get ourselves acquainted with the definitions in this area.

Now, when we talk of soft matter and some of you who are listening in to this course may have already got to know somehow the relevant keywords for example you might have heard of the word the colloids, you might have already heard of word Viscoelasticity, so there are a many different keywords that are operative in this domain, and I do not want to go over all of them but, two or three of the most important terms we should be familiarizing ourselves with at very onset. And if later on there are more terms we will familiarize it, familiarize ourselves with them, as and when required.

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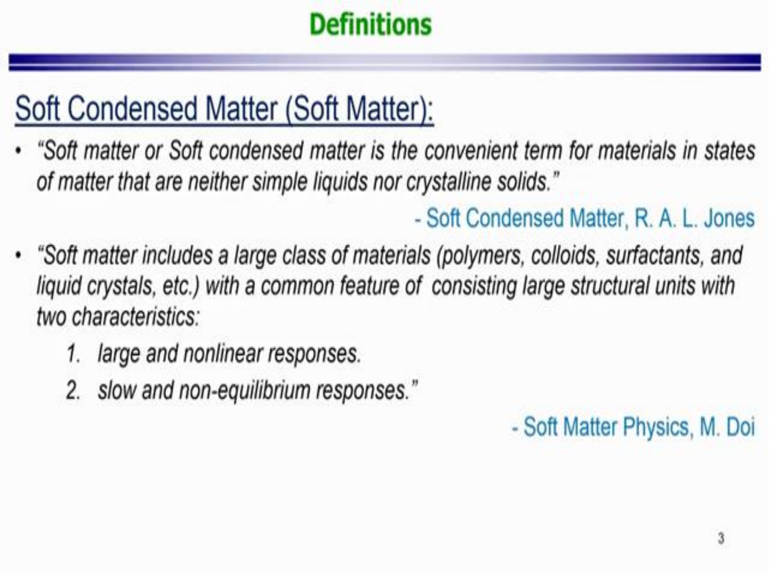

So, the first term obviously since, the course is called soft matter the first important term we want to understand is the term soft condensed matter or soft matter, now according to R. Jones the book Soft Condensed Matter he defines soft matter or soft condensed matter as a convenient term for materials in states of mater that are neither simple liquids nor crystalline solids.

As we can say this definition appeals somewhat to your intuition and it is asking you that before you even familiarize yourself a soft condensed matter you should know what simple liquids are and what crystalline solids are and soft matter is a state of matter that is somewhere in between these two, so it is appealing to your intuition in the sense that what is an in between state you should be able to understand on a slightly intuitive level.

Now, simple liquids whenever we say liquid probably the most common liquid that human can or people would think of would be water. When we say crystalline solid you might probably think of steel, or some metal as very good examples of the states of matter. So, soft matter is probably something that is in between these two, and this intuitive idea is actually very helpful because, it does let you figure out what a material probably is.

In another book the which is called soft matter of physics by an author Masao Doi he states that soft matter includes a large class of materials and then he goes on to numerate some of the possible materials which is polymers, colloids, surfactants, liquid crystals, etc. with a common feature of consisting of large structural units with two characteristics. Large and nonlinear responses, slow and non-equilibrium responses.

So, the first part of this definition is still appealing to intuition in the sense that it is trying to enumerate somehow the possible soft materials that are out there. And then it gives two important characteristics of them, and these characteristics are actually they come from a statistical mechanics or microscopic view point, we will take these up, later on in the course okay,

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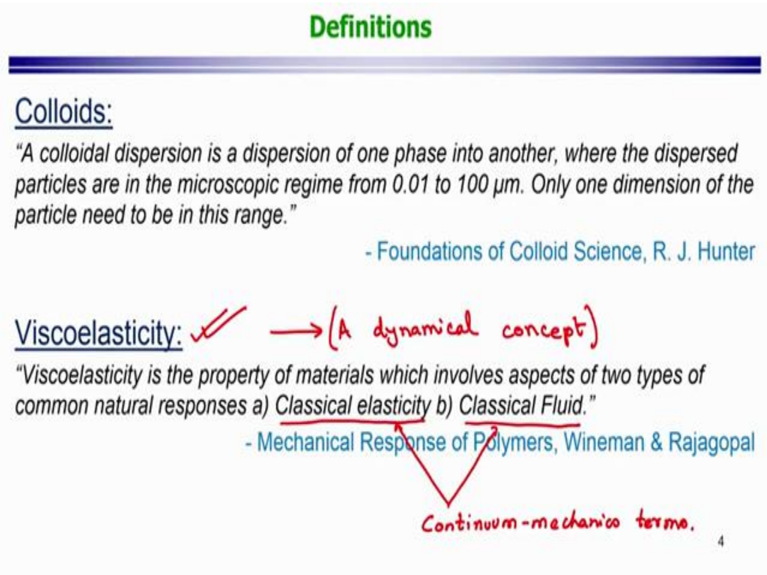

So, we already saw the term colloids, okay so, maybe we should define it at this at the very onside this will probably be using this term quite a bit, so colloid is a colloidal dispersion, so word colloid is a short form for colloidal dispersion, so a colloidal dispersion is the dispersion of one phase into another where the dispersed particles and the microscopic regime and then the regime is given to you is from 0.01 which is 10 nanometers to 100 microns. And this definition also states that only one dimension of the particle needs to be in this range. And this is taken from foundations of colloids science by R. Hunter.

So, this term called colloids we will, also encounter in our in due course but, a term that is going to be a very important for us and we are going to use that quite a bit, at the very onset is viscoelasticity and viscoelasticity here is defined as the property of materials which involves aspects of two types of common natural responses, classical elasticity and classical fluid. This definition which is taken from the book Mechanical Response of Polymers by Wineman and Rajagopal.

Initially it does seem like it is also appealing to your intuition in that it is asking you to think of a classical elasticity and classical fluid and then the viscoelastic response is somewhere in between.

Now, the classical elastic response of the classical viscus fluid these are ideas from continuum mechanics. And in the continuum mechanics we will, see that both these two terms are understood very well, they are understood with the mathematical precision so we will use this word in the beginning quite a bit, and viscoelasticity one more thing that I would like to mention here is that this is also a dynamical concept what do you mean by when I say a dynamical concept it means that, we are going to look at classical elasticity or classical fluid behavior or even or the viscoelastic behavior from the prospective of the application of a force on a materials and then understanding the response of that material to that force.

Okay, so what we have done till now is we went over some good books as I said, my apologies to the books which I have left out there are many of them I could not put all of them here, we looked at some of the definitions and now what we want to do is look at the historical context and we will look at the ancient time keeping systems but, before we look at the historical context.

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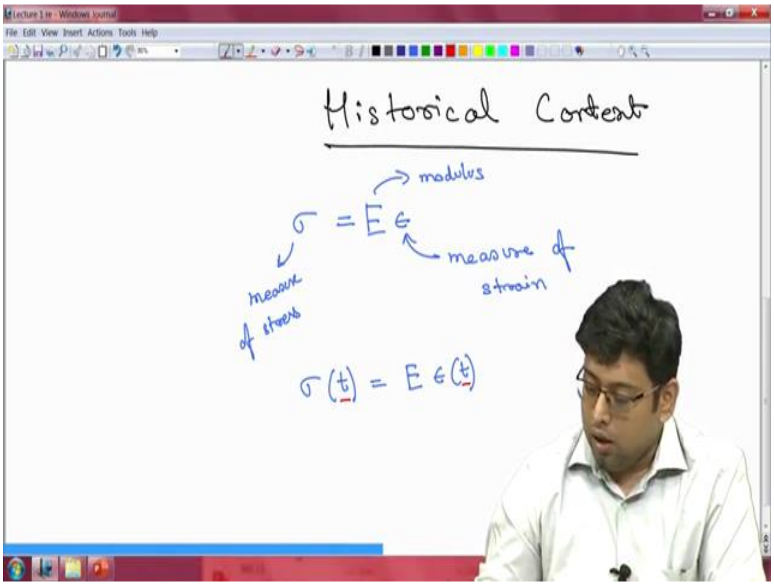

So, going to just talk about, before we talk about historical context I would like to stop for a moment and I would like to give you a reason why we are doing this, so remember, if you may, so most of you who are attending this course should be familiar with what a classical elastic response is and you probably remember from your undergraduate classes that for elastic body we would write sigma equal to E into epsilon where epsilon is a measure of stress sorry, measure of strain some measure of strain in the system, this is a measure of stress and this is some modulus, elastic modulus.

This equation is better written as sigma of t into E times epsilon of t and I have deliberately written now, t into this because, I want to emphasize that the strains and the stresses can be functions of time but, what this equation is saying is that the instantaneous stress depends upon the instantaneous value of strain and vice versa. It almost implies that the system response is infinite, so if you put some amount of strain this amount of stress is going to be instantaneously generated.

But we know that, systems take time to react, whenever you apply a force, or are trying study a system so, systems have their own responses so, there are usually natural time scales that are associated with a system's response. So, it is important to understand what these time scales are and how they are relevant in this particular context. Which is why I want to highlight a couple of things from the historical context here.

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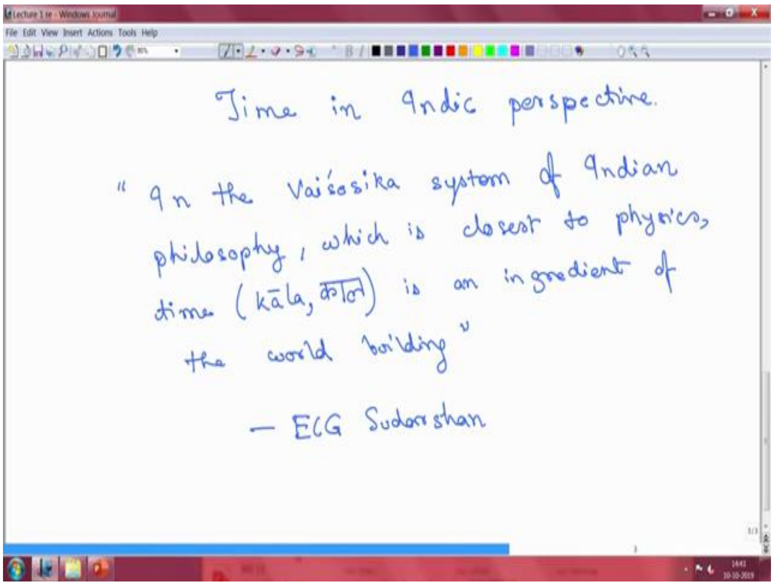

And I just want to look at the issue of time in the indict prospective because idea of time was treated in a lot of detail in some of the indic sciences and I would like to use a very this is a very, this is the quote I very much like so, maybe I will start with that and this quote is attributed to ECJ Sudarshan in his essay time in the Indian tradition.

And he says that in the Vaisasika system of Indian philosophy which is closest to physics time or often written as Kala, if I have to write it in Devanagari I would write like this, is an ingredient of the world building. And this is attributed to ECG Sudarshan and it can be found in his essay time in the Indian tradition and the reason I am bringing this up is because, the issue of time was dealt with the in a lot of detail in the Indian tradition and the ancient understanding of time was interestingly extremely sophisticated.

Because, they understood that there are many different natural time scales and they use these different times they not only observe these time scales they not only recorded them but, they used it with a lot of creativity.

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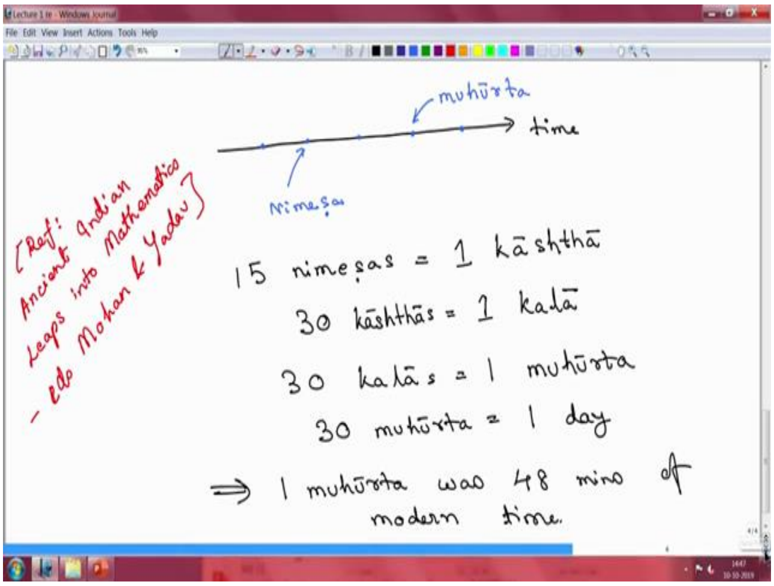

So, for example, they realize so if just draw time axis, they realize that there are lot of different units of time that are possible, and one such unit of time is called the Nimesa sorry, I put the here on different location, Nimesa and another one was Muhurta and a Nimesa was defined as the time takes for blinking of an eye, and this built up different time scales on this one unit that they identified and they using multiplicating factors they built up different time scales in.

For example, and here before I write the different time scales I must warn you that different authors sometimes differed in the use of the different time scales Muhurta could be different numbers for different peoples.

So, this is from a Suryasiddhanta and here they have defined 15 nimesas as or 15 twinklings of an eye, as one kashtha and 30 kashthas made 1 kala, and 30 kalas is 1 muhurta and 30 muhurtas amounted to 1 Divas, 1 day. So, in fact you can do a very simple calculation 1 muhurta was about 48 minutes of modern time and reference for this I will just also give you the reference material for here.

The reference text here is, ancient Indian Leaps into mathematics and it is edited by, its editors are Mohan and Yadav. Now, they even designed smaller time scales which they understood as responses or natural time scales that are inherent in certain actions so for example, one more time scale was called the truti and the truti was defined as.

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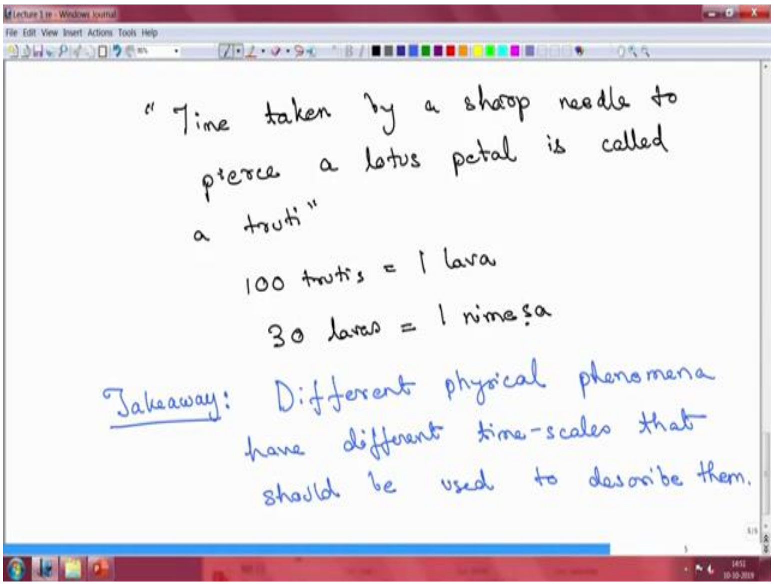

The time taken by a sharp needle to pierce a lotus leaf, lotus petal is called a truti and they even again just like previous time they built up a so 100 truties would make up 1 lava and 30 lavas will be equal to 1 nimesa so since, smaller time scales are defined and massively larger time scales are also provided for example the yuga and the mahayuga, etc.

And these time scales were used for because, they realize that there are different events which correspond which have different inherent natural time scales. So, a cosmological event has to be or has to be described by a time scale that is natural to the cosmological event. So, a cosmological event may be described by mahayugas or yugas. Whereas, a small time scale that you are experiencing in daily life might be described by muhurta which is basically based on the idea of the day. Right, which is also again as you realize is a natural time scale that is set by our planetary system.

And they even found out that there were other time scales which are natural for example the blinking of an eye it take some time for you to blink the eye and that they used to define a unit called the nimesa and similar other. And as I said before one important thing to keep in mind is that different authors sometimes use different time scales and they would use the same name for example so, one has to be careful so, Pauranic and astronomical time scales for example could differ despite the use of the same name.

But, the important take away here is not the accuracy of the time scales so whether they are right or wrong but, rather the important take away here so, what is the take away why are we discussing this, so the take away is that different physical phenomena have different time scales that should be used to describe them, and the idea that systems have an inherent response time in a certain sense, and this idea will also be key to our understanding of soft matter. This idea the different physical phenomena has different response times or have different inherent time scales that are associated with them.

This comes up in a number or the non-dimensional number that we are going to use quite a bit, in this course.

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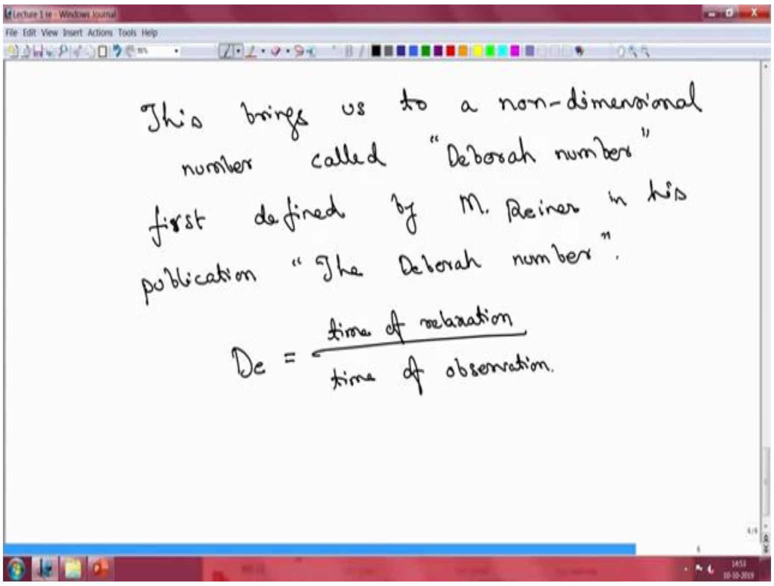

So, this brings up to a non-dimensional number called the “Deborah number” and this was first defined by M. Reiner in his publication which was called “The Deborah number”. And he defined this number as here is on the top is the time of relaxation we will see what that means is, and this is time of observation.

So, here we see that the there are two important numbers this is the numerator and the denominator, the numerator and we will see this in more detail as we go through the series of lectures where the numerator in a sense is designed to take into account the idea that when you apply force on a material, the result is not always instantaneous.

Or sometimes if you withdraw the force, that result is also not instantaneous although when you probably learned about fluid mechanics you learned that the moment you apply shear force on fluid it starts flow and flow is instantaneous with the application of the force. And that may not always be true. The system might have a certain time scale associated with its response to a given force and the numerator is designed to take that into account.

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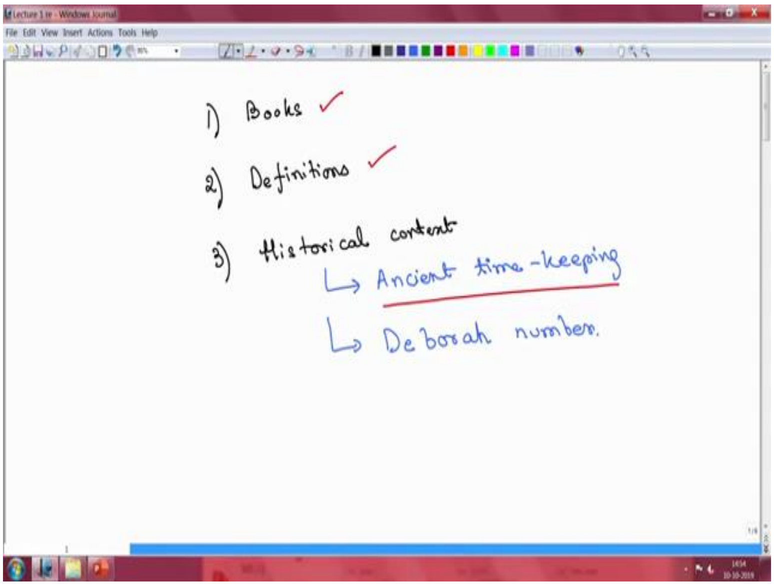

So, in today's introductory lecture what we had promised you is we will go over few things which are the different books that you might want to look up, a refer to for this course, we looked some of the definitions we only looked at handful of them and if we come up with more terms we will define them as and when we needed, but the terms that we are going to use quite a bit is called the term viscoelasticity and we are also going to look at the term soft matter but at a slightly later stage you are look at what that exactly means.

An in the historical context we looked at ancient time keeping and how, natural time scales where observed and recorded and used very creatively to keep a tab on time and this eventually flows in to the idea which we just started to discuss today which is the Deborah number and in the next class we will look in more detail at the topic of Deborah number okay so, we will end our first lecture here.