Properties of Materials: Nature and Properties of Materials III
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Lecture 01
Introduction

So, welcome to this new course on Properties of Materials which is essentially 3rd part of this Nature and Properties of Materials series.

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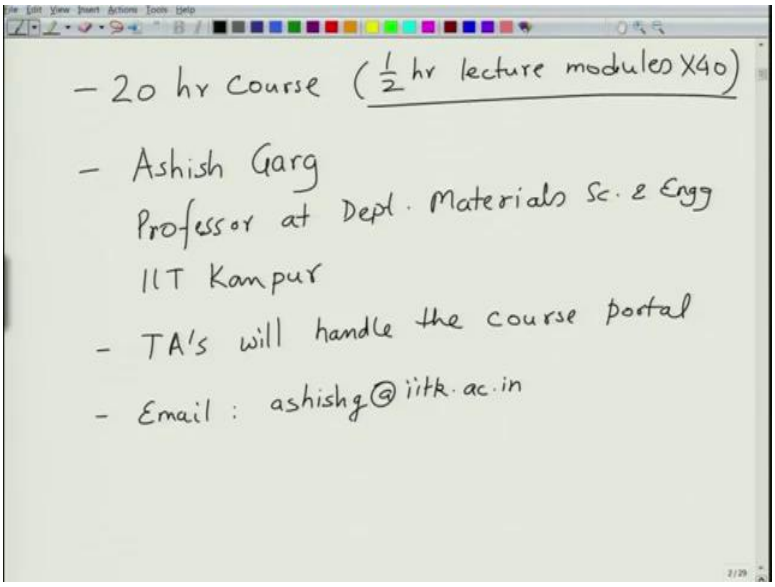

And in this course say so let me just give you some brief statistics of the course, so it is a 20 hours course which means you will have essentially half an hour lecture modules and you will have 40 of them.

So, they will constitute total of 20 hour lecturing and my name is Ashish Garg, so and I am a Professor at Department of Materials Science and Engineering at IIT Kanpur. There are two TA's which are assigned to this course, so TA's will handle the course portal and they will respond to any queries that you might have however if you need to contact me you can email me on, so this is my email address in case you need to contact me.

So, this course basically is intended for if you are B Tech student of metallurgical engineering material science in early stage B Tech student or if you are a student of mechanical engineering or if you are a student to chemical engineering physics or even chemistry or nanoscience and engineering various disciplines who want to just get a introductory description of materials properties.

Especially mechanical and electrical properties, then this is suitable course for them. So, essentially it is a under graduate level very preliminary course just giving you a basic introduction of materials properties with regard to their functionality.

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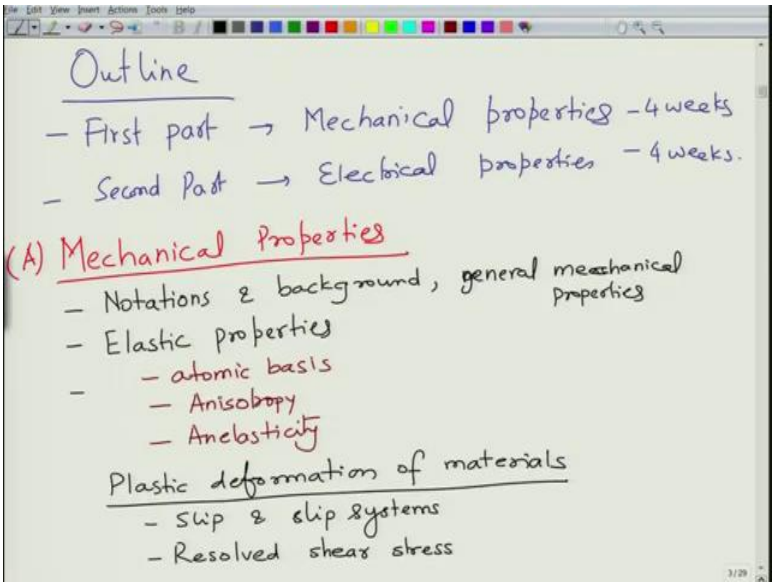

So, let me just give a brief description of the outline of the course. So, in this course we will begin with, so course will it has two major components. So, the first part of the course, we will talk about mechanical behavior of the materials essentially the Mechanical properties and the second part we will talk about Electrical properties.

And this first part will last for nearly a four weeks. So this is 4 weeks of Mechanical properties and then we have four weeks of Electrical properties. So, coming to Mechanical properties we will begin with our with the Notations. So, essentially what are the major notations and then we will talk about the, so notations as well as some background, so background in terms of differences and behavior of materials and so on and so forth.

Then we will talk about Elastic properties. So, notations, background and I can also add basic like general mechanical properties that you encounter in various applications, so you see various application on day to day bases. So, what is the relevance of mechanical properties those applications just to give a brief idea.

So, once we do that background stuff after that we will move on to what we call as elastic properties in this elastic properties we will look at basically, we will look at the atomic bases

of elastic properties, we will look at anisotropy and then we will look at anelasticity. So, these are topics that we will cover under elastic properties.

And so this will generally constitute nearly one week of lecturing and after that we will move on to that plastic deformation. So, we will talk about plastic deformation of materials in this essentially we will talk about how does the plastic deformation happen which means we will introduce the concept of slip which means we talk about slip and slip systems and then we also invoke the concept of what we call as resolved shear stress and then so this will talk roughly week two and then we will move on to week three where we will talk about plastic deformation in details.

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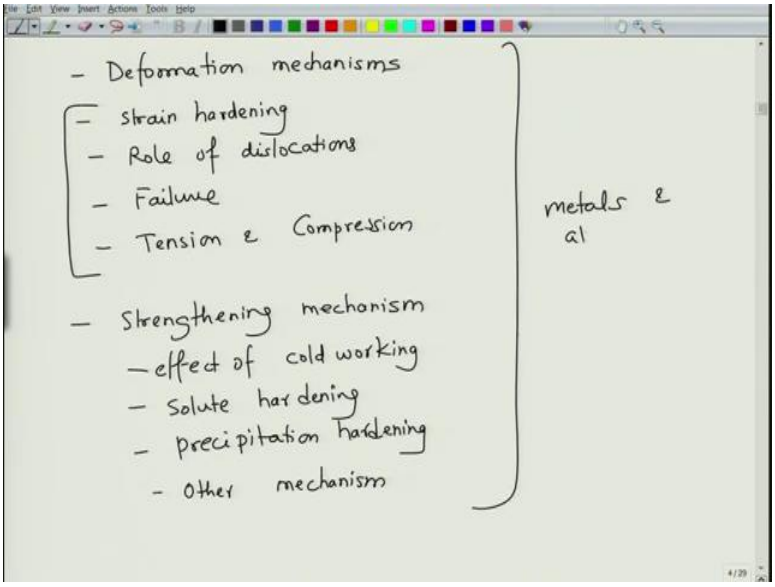

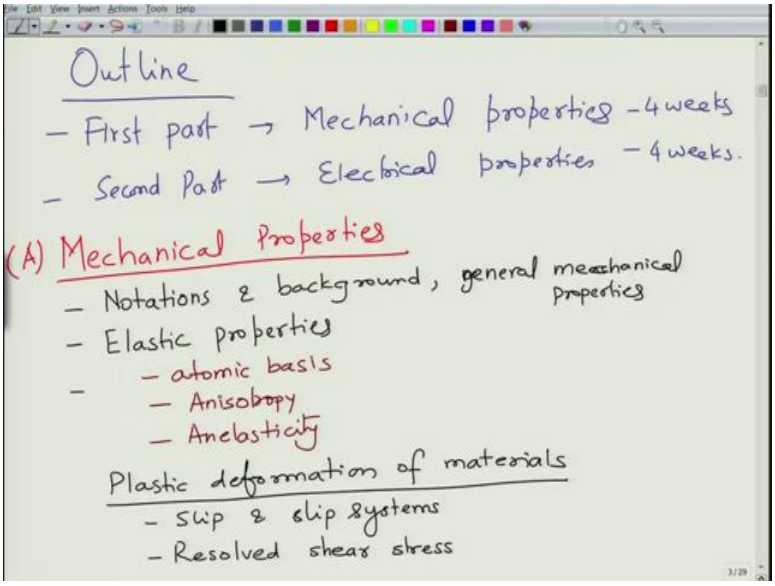

So, we will look at deformation mechanisms and deformation mechanisms we will look at strain hardening, we will look at role of dislocations and failure and then we will also look at the difference between tension and compression. So, basically what happens when a material is deformed how does it harden, what is the role of microscopic mechanism of this location in affecting the deformation how does it fail and what happens when you what is the difference between tensile and compressive testing of materials.

And then once we have done this, we so this is deformation mechanisms, then we move on to what we call as strengthening mechanisms that using this knowledge of deformation theory how can you make a material strong. So, strengthening mechanisms will basically include effect of cold working and then we will look at solute hardening, what happen when you add some element to a material, then we will look at precipitation hardening and then we will look at some other mechanisms that might be prevalent.

So, this is what basically we will talk about the mechanical properties, we will not deal so much with the failure and facture aspects of material we will mostly deal with the deformation in materials especially in metals. So, this is mostly to do with the metals and alloys. So, in some sense you can say that the mechanical properties module of this course is primarily with mechanical properties of materials and that too essentially a deformation behavior and strengthening mechanisms. Because we do not have enough time for fracture and fatigue.

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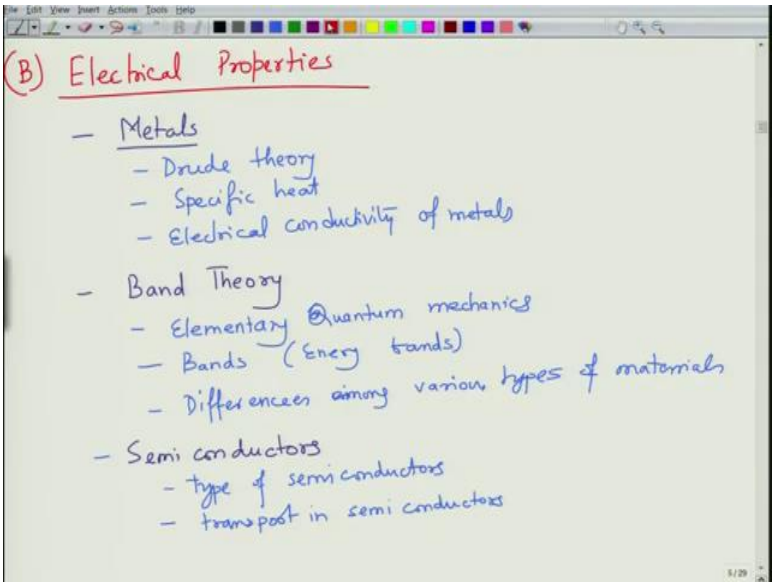

And then we will move on to what we call as Electrical properties. So, in electrical properties we will start with metals. So, in metals we will first begin with a Drude theory and then we will do some analysis in terms of specific heat calculation or specific derivation and then we will look at what is the electrical conductivity of metals more sort of expectable theories.

Once we understand this metals part, we will move on to semiconductors and this requires such to introduce bands, so we will go to Band theory. In the Band theory we will do elementary quantum mechanics we will not get into details of it we will just introduce elementary quantum mechanics and then bands energy bands basically these are energy bands.

Differences between metals and semiconductors, various types of materials essentially metals semiconductors and insulators and then we will look at, so once we have that we will be able to move on to what we call as semiconductors and we can look at different types of semiconductors and then transport in semiconductors.

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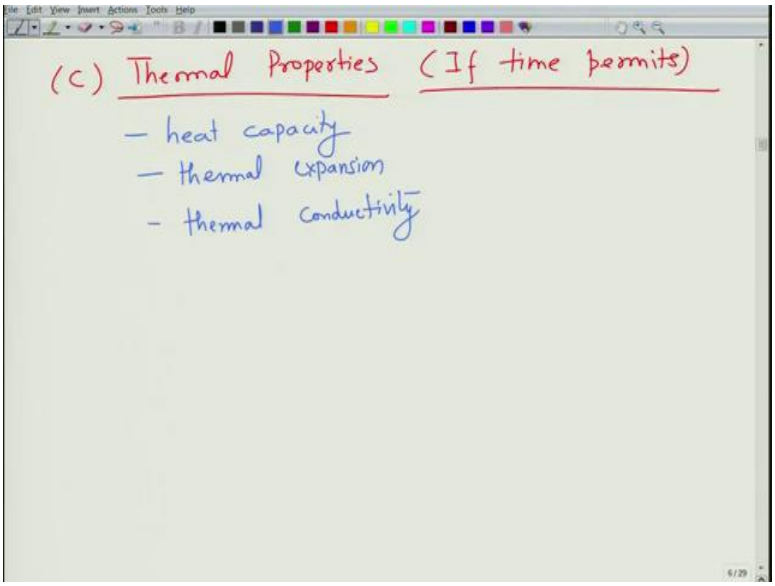

And finally as the last exercise if the time permits we will try and do thermal property, if time permits, then this thermal properties, we will try and look at stuff like heat capacity and thermal expansion and thermal conductivity. So, these are the contents that we are going to follow in this course, primarily on mechanical and electrical properties of materials especially metals and semiconductors, mechanical properties of mainly of metals and electrical properties are mainly metals and semiconductors. If time permits we will come to thermal properties in the of the course.

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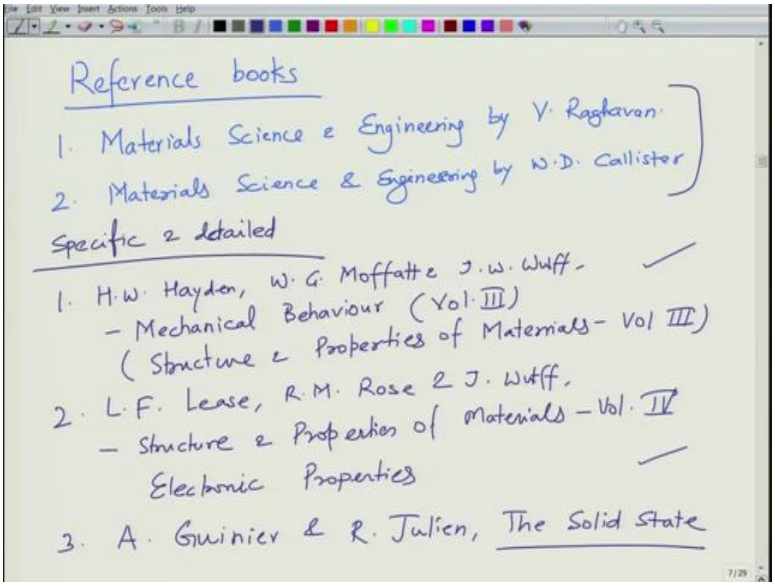

Now, let me give you some references for the, so let me give you reference books that I would recommend you to go through, so first book is Materials Science and Engineering by V. Raghavan, second one I would recommend is again Material Science and Engineering by W.D Callister and then more specific and better books I would recommend one is, so first is this H.W Hayden, W.G Moffatt and J.W wolf who have written this marvelous four volume set out of this mechanical behavior volume three and the title of the book is essentially the structure and properties of materials.

So, basically it is a structure and properties of materials essentially volume three, it is an excellent book if you can get it I think I would strongly recommend you to go through it and then second one you can read the fourth volume which is L.F Lease, R.M Rose and J. wolf which is again structure and properties of materials volume four and this is electronic properties excellent book.

Go through these two books for the sake of this course especially the first two or more generic in nature these are more specific in nature these are actually I would say the recommended book I would suggest you go through them and then there is another one which is very nice book especially in terms of thermal properties and electrical properties is A. Guinier and R. Julien the solid state, it is again a good book if we can get hold of it this is a very nice book especially for electrical and thermal properties of materials.

So, this is what the outline of the course is. Now, let us go through a brief sort of walk through, what why do we want to do this course? Now, the reason why we want to do this

course is because properties of materials are related to the application that we see in daily life.

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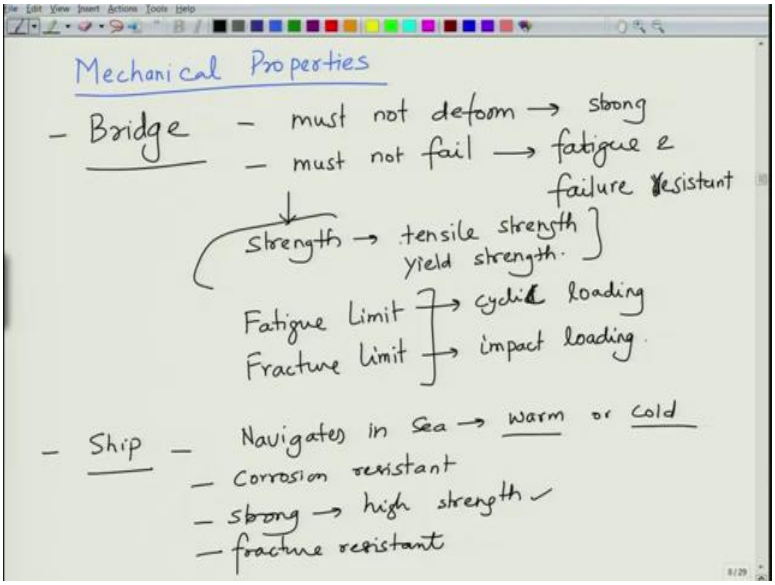

For example when you talk about mechanical properties, so we have variety of applications around us, for example if you look at something called as bridge. The bridge on which we walk, vehicles pass through every day and bridge has to be so what must bridge what must not happen with the bridge? Well the bridge must not deform, bridge must not fail which means it must be strong, it must not plastically deform essentially and it must not fail which means it must be fatigue and failure resistant.

Fatigue meaning because there is a continuous variable loading which means sometimes the load is high sometimes the load is low sometime and load is a varying nature as a result which is called as cyclic loading and as a result this is called as fatigue loading and then failure because of shocks it might impact loading is also there. So, both cyclic as well as impact loading are there that is why we talk about fatigue and failure.

So, what it must have? Basically it is going to be define by properties such as it must have high strength and in case of a strength generally we talk about tensile strength or yield strength and we will see what these terms are as we go through the course. So, these are certain terms. Similarly, when we talk about these failure properties we are talking about fatigue and facture.

So, we talking about fatigue limit and talking about of facture limit or failure limit. Now, fatigue and facture we are not going to discuss in this course. So, we will keep them out of it, but basically they are fatigue is because of cyclic loading and facture could be because of impact loading essentially it is a sudden failure.

So, these are basically because of, but is very important is the strength that a bridge must be strong. Similarly, for example when you look at ship, a ship navigates in sea, sea could be warm or cold, if it is Indian Ocean it could be warm, if it is North Sea or Atlantic it may be cold.

Now, a ship the material which is used to builds must be corrosion resistant of course because it must not corrode in saline water. But at the same time it must be strong, because it under goes collision with the icebergs and other thing. So, it must have high strength and also ships are heavy they have to carry lot of loads.

It must have high strength at the same time it must also be fracture resistant especially at lower temperatures such as when it goes to North sea or Atlantic you must have seen the movie titanic where titanic underwent the facture because of lower temperatures. So it must be facture resistant. So, it must have high strength for these applications as well as high facture resistance. So, this is the importance of mechanical properties in these applications.

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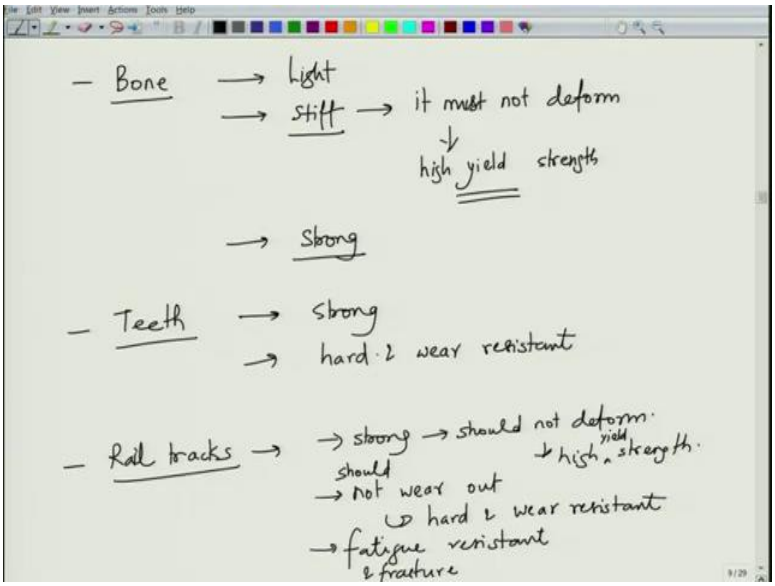

Now, coming to coming closer, now you can see within your body itself we have bone. Now bone if you look at the bone hand bone or your leg bone the bone must be it must not be very

heavy, so it must be light, but at the same time it must be stiff, the bone must not deform, which means it must have what we call as it must not deform by which it we mean is that it must have high yield strength. There is a term called as yielding, yield means give way, that or buckle it must not buckle it must not plastically deform it should remain it should retain it shape.

So, it must be stiff, it must not deform, it must not easily deform and so we will see what yield strength is. Similarly, bone must be strong, bone must not also easily fracture. Now, if you look at teeth, teeth must also be strong, so we have lot of these advertisement from Colgate and stuff like they says strong teeth basically by strong teeth, we mean the teeth must not deform while we achieving the food or biting anything.

Similarly, they must be also hard, only because there are hard and wear resistant you can bite and chew things. Now, if you at things like rail tracks, rail tracks must be strong they should not deform, which mean they must have high strength. So, basically here we are talking about high strength and we will see what kind of strength do we mean.

Rail tracks should not plastically deform which means they must have high yield strength, they should so we can say high yield strength, they should also not should not wear, wear out which means they must be hard and wear resistant on surface. But they should also be fatigue resistant, because railway track also go cyclic and impact loading as a result fatigue and facture resistant resistance is important.

So, they have to have high yield strength they should have high hardness and high wear resistance. But at the same time they should also have high fracture resistance and high fatigue resistance and some of these properties can be quite contradictory or quite counterproductive to each other as a result we have to balance out these properties in a given material. So, these are certain examples which demonstrate what kind of properties mechanical properties we are expecting in different materials.

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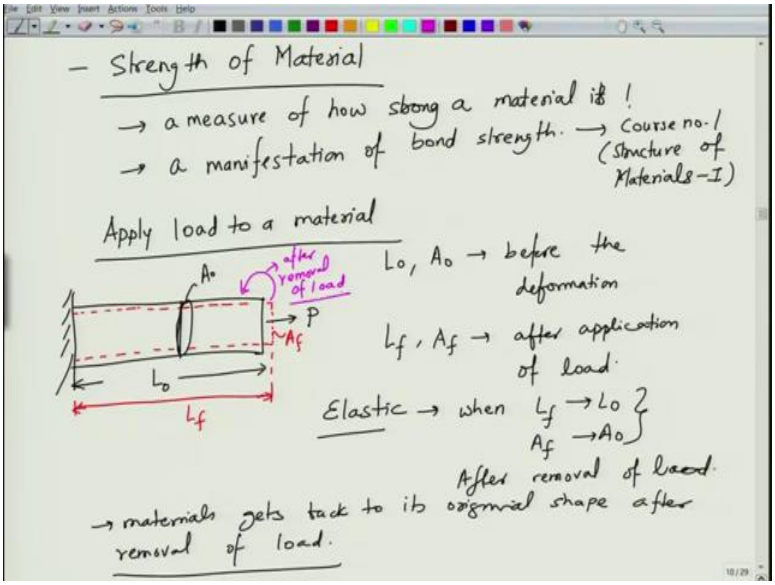

So, in this course we are mostly dealing with what we call as basically strength. So, we are talking about the strength of material, strength of material is basically a measure of how strong a material is and essentially it is also a manifestation of bond strength. So, to know about the bond strength you need to do course number one which is on structure on materials.

So, that is where we talked about the structure of materials nature and properties of materials part one. So, what is this, this strength of material. So, basically what happens is that, when we deform any material, so let us say when you apply load to a material. Let us say you have a beam, this beam is of length L. Then when you apply the load to this material let us say you apply a load P, this beam will get elongated a little bit and its area will cross sectional area will reduce.

So, this is, so the black one is it has a length L naught and it has a area which is let us say cross sectional area is A naught, that is before the deformation. So, L naught A naught is before the deformation. Once you apply the load it takes a length Lf and area. So, it will have a area Af and length Lf. So, this Lf and Af are the after application of load.

So, coming to a few terms a material is elastic, when Lf goes back to L naught and Af goes back to A naught after removal of load. So, you might have seen that in clothes we use this elastic and you can see that when you stretch them they stretch longer when you apply load. For example, rubber or any other polymer and when you release the load they get back to their initial dimensions.

So, basically elastic material be material gets backs to its original shape after removal of load. So, this is what is elastic behavior, so when you release the load the material will so this is, we can say this will go back to this after removal of load.

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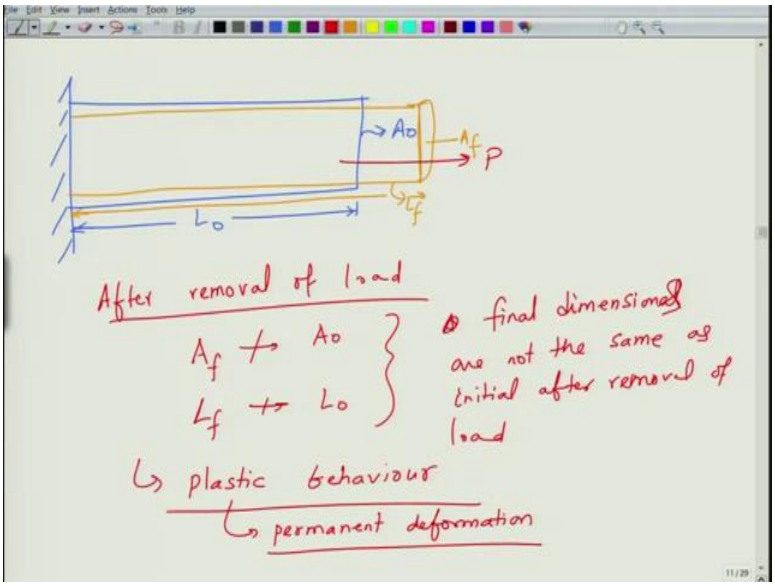

Now, what happens when you when the material does not so you might have other situation in which, you have this beam with length L naught, area A naught and you apply the load such that becomes longer and thinner. So, this is Lf and this is a cross sectional area Af. Now, after removal of and we apply a load P.

After removal of load Af does not go back to A naught and Lf does not go back to L naught, which means final dimensions are not the same as initial after removal of load this is called as what we called as a plastic behavior, material has under gone what we call as a plastic deformation.

Plastic means it has gone some deformation in it, so there will be some initial deformation which is elastic in nature but beyond that it has gone a deformation which is called as plastic or we say a permanent deformation. So, material does not come back to its original dimension its size, its hinges and it does not get back to its original one upon removal of load. So, these are some basic concepts that we have introduced in this lecture, we will get into details of these concepts more in the next lecture. So, we will stop here and we will continue this in the next lecture. Thank you.