Physics of Materials

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Lecture No. # 01
Introduction Physics of Materials

Hello, and welcome to this course on physics of materials, I am doctor Prathap Haridoss, I am a faculty in the department of metallurgical and materials engineering at IIT Madras, and my contact information is there for you, my Email address is my first name at iitm dot ac dot in. So this is a course on the physics of materials, we will it is a forty lecture course, and it is aimed at primarily at students who are doing their under graduate programme in materials science and engineering or in materials engineering in a variety of colleges. The way this material will be presented through this course will be such that any student with an engineering background will be able to access it, although it is primarily aimed at materials engineering student.

And to that degree the material being presented here, the information being presented in this course will be fairly self contained in the sense that, if we just follow the information presented here and carry out any associated exercises. I believe when the course is complete when the forty lectures are complete, your understanding of the subject will be such that, you will be able to access a lot of other reading material that is available outside, and it will improve your confidence in this kind of material. So, as I mentioned this is again self contained course, we will use references I will give you references, but in general what we cover here, will account for any background that information that you require, and will develop that background to a suitable degree.

The only assumptions here are that you are an undergraduate engineering student, so some element of the associated mathematics is assumed, but even then even with respect to the mathematics involved, where necessary some amount of the background information will be developed for you, so that there is no loss of continuity. In general that is the intension, because this material spans few different areas of science and engineering, and therefore it is sometimes easy to present this material by simply asking you to look up a lot of references, but I believe by doing so you will loose some of the continuity associated with that material.

So therefore, even though we have a limited time of forty lectures, where necessary where relevant the appropriate background we will take a slight detour to develop the appropriate background, so that the material goes on in a very smooth and continuous manner. And in that sense, as I mentioned the intended audience is an undergraduate student, and therefore it will be aimed at precisely that level.

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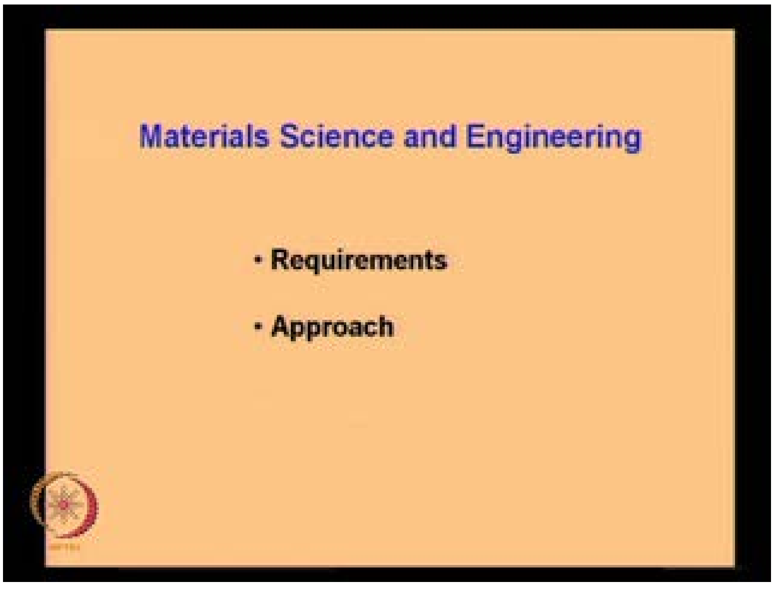

So, in this class what we will do is, I will lay out the material that we are going to cover in this forty lectures, I will show you the... I will present you the approach that we will take and why we will and we will discuss why we are going to take that approach, we will look at what all kinds of topics we will cover and perhaps a little bit of what kind of material it relates to that you may be familiar with, I will also address some of the difficulties that you may face that our student first encountering this kind of a material might face and we will discuss that little bit. So that, we understand so that you are not caught by surprise, so you understand what is it that may require you to do work and what is it that you will that may challenge your current understanding of concepts and so on.

And with respect to this course, what are the key challenges in terms of finally getting a grasp of this information and so on. So, we will look at all that we will look at the syllabus associated with this course the topics associated with this course, how we will go about it and such... So, that will be the thrust of this first class and as the course goes on my suggestion is that as a when required, please look up the information in this first class, because it will lay out the broad areas of this course quite comprehensively. So that, you will know the layout of the material and you will know where you are at a given point in time and how it relates to the other materials, that we are covering in this course.

So, if we take now, in terms of I think the first question we need to answer or we need to at least appreciate is why we are going to go through this material, I think that is a very critical aspect of the subject because, if we have a good feel for why we are going through this material, it will become easier to follow the new answers associated with this material. So, if you look at the broad area of material science and engineering and I will say this from a from a sense of a professional, who is in in this area, if you are a professional or you become a professional in this area of material science and engineering.

Then you will find that, there are very broadly of course this is a this is a bit of a generalization, but it is an it does capture the gamet of activities that people intelligent are participated very broadly you could end up being an engineer in a technology form or in a in a in a form that is producing things that are associated with materials or you could end up as a scientist, where you are in some research laboratory possibly creating new materials and so on. So, these are two different areas of material science and engineering, what happens is that the requirements for these areas are somewhat different. The kinds of work that you do you end up doing on a day today basis tends to be different.

You may not consciously realize this especially if you are already, if you end up in a particular job and you stay in the job long enough, you may not realize this, but if you are an engineer in a in a company you may be doing the kind of activities that you do in a day, may be quite different from the kind of activities that a scientist does in his or her research laboratory. In material science and engineering what happens is that, because of the immediate goals that the engineer faces in a form or scientist faces in a research organization his or her research organization. Often the information or the knowledge that they are missing out, by just staying within their range of activities is often not immediately aware to the... is not immediately known to them.

And, what I would like to do is to take few few moments of a time to get a sense of what is it that you may miss out, if you just stay as an engineer in in a typical form or if you become a scientist in a typical research organization. You see that, when you are an engineer in a typical form, the the kinds of constraints that you face are such that often you need to quickly find out materials for a particular activity, so that is the kind of a what shall I say problem definition that comes to you. A typical problem definition that comes to you is to get a particular material to suit a particular purpose, so that is the kind of problem definition that you are faced with.

So, this problem definition is such that often it requires you to have a very good information database at your disposer, so you have a lot of information database, the your talent are what you provide is your familiarity with this database familiari familiarity with the knowledge of material properties of various materials and so on, which enables you to quickly come up with material that has a certain set of properties. So, this is the kind of activity that an engineer would be required to do. So, as I mentioned this is a generalization, but it does I think in some ways capture this general idea of what you would end up having to do.

So most often this sound understanding of material properties knowing what kinds of materials have, what kinds of limitations, what kinds of positive aspects, is the kind of knowledge database that is very useful for an engineer in a form. And it is the kind of the knowledge database and the familiarity with this knowledge database that adds to the credibility of that engineer. On the other hand, if you are a scientist in in a research organization. This information is useful, but you tend to focus more on the new answers of a specific property, you tend to focus more on a particular property, you try to enhance a particular property, you try to see, if there are limits to the extent to which some particular property can be enhanced in a particular material and so on.

So, and sometimes you look at the science behind the property, you try to understand what is the phenomenon that is occurring, which enables that particular property to improve are are get limited in some way. So, these are two separate kinds of problems and as I mentioned these two kinds of aspects of material science and engineering, simply because of the organizations, where people participating in this kind of work or involved tend to often tend to stay separate from each other, what is necessary is often, if you wish to really make a totally new material a totally new material a totally new material capable of meeting requirements that have so for not been encountered, then a sound understanding of both is becomes necessary.

So, it really helps for an engineer to learn more about the science of material and for a scientist to learn how engineering materials are utilized. So, both of these tend to be necessary, so that you can really benefit from both and I I mention this again that what I have said so for is a bit of a generalization, there are engineers who are already doing this, there are scientists who are already doing this. So, I am just talking of in in general terms, how problem statements tend to be separated from each other. So as I mentioned, what we are now looking at is from a materials engineer perspective, you have look up tables and so on. We would like to go further than that like to understand the science behind how those information present in a stable concern.

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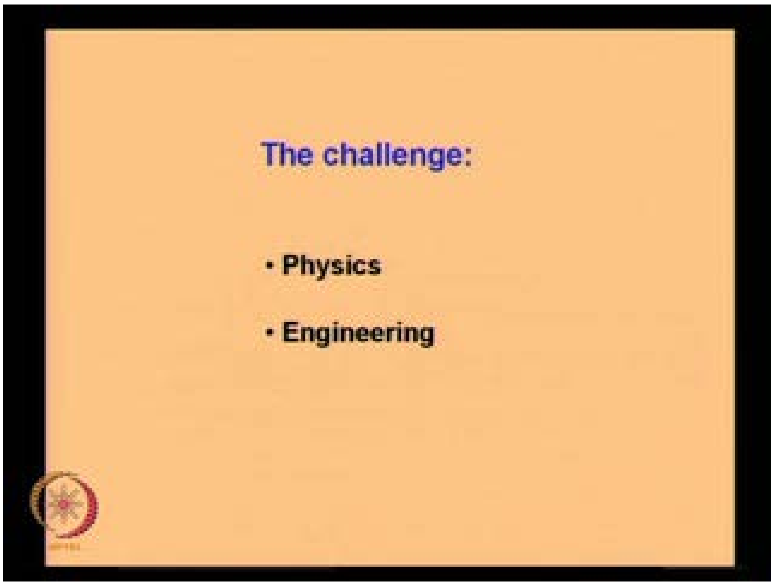

So, as I mentioned the challenge for us is to merge the physics and the engineering that we encounter, the reality is that they are already merged, so it is not they are separate, but if you if you go through an under graduate education process and you go through a typical the kinds of courses that are available and people take. You... As a student whose encountering this materials for the first time, encountering all of these study material for the first time. You will feel somehow that these are not connected, you learn the physics independently; you learn the engineering independently; you learn the math independently; you learn the materials engineering independently and so on.

These tend to stay disconnected, it takes several years of experience in a work in a work place, where such aspects are intertwine only the only after several years of experience in such a work place, do you recognize, do you feel comfortable with the linkages between all of these subjects. Till then as a student it is not surprising, if you if you find yourself in a situation, where somehow these various subjects that you are learning seen to be disconnected. This is a natural result of the fact that specialists in particular area are teaching their specific subject and so they they teach it with full depth and detail in that area.

And as a student, you would learn them independently and it will be up to you to somehow try and connect these subjects. So, physics is an engineering something that we would like to merge in in the form of our understanding of it, it is as I mentioned it is already merged, it is not that we have we are creating something new here. These these are already merged it is they they are never really separate anything, you get already has so these concepts merged in them. We would like to formally in our in our understanding of it as an undergraduate student try and get them to be something that we feel comfortable are merged with each other, so this is what we will try to do.

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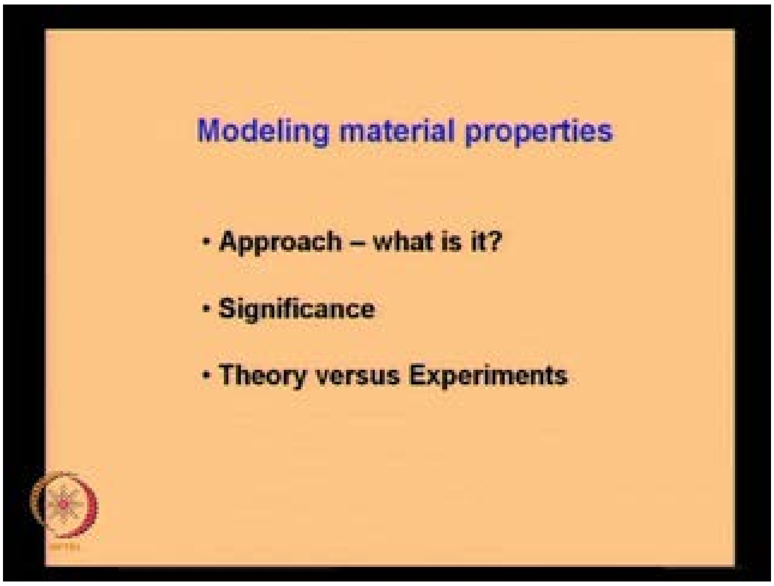

So in this regard, in this course physics of materials, we will spend some of our time looking at modeling of materials. So, in our and this is necessary for us, because it is a very essential part of the idea that I just mentioned, which is to merge the physics and the engineering, where the physics when you go down to an atomic scale and electronic scale and so on. There you understand intimate interactions between particles and then you would like to extrapolate that, down to something that you can see in a physical sense. So in a physical sense meaning you have a solid object given to you and you expected to have some material material properties.

So, what we need to do is to understand how something that is going on at a sub atomic level, eventually add sub to something that you see in a macroscopic sense, something that you actually see in a macroscopic sense and something you can measure, so these is something that we need to do. To do this the general approach is to generate a model for a material and through this course there will be models that we will look at. So even before we get into those models which is what we will do in in the latter classes, what I would like to do today is to briefly discuss, what we mean, when we say that we are creating a model for a material. And what is that approach that is involved in it, what is the significance of it and so on.

So basically, when you say you are modeling a material, what it means is that, you are taking a set of rules that are based on science and you say that the material are it is constituents, may be the atoms in the material, may be the electrons in the material, may be the nuclei in the material. Something you are you are taking some fundamental aspect of the material that you are aware of and you say that that those fundamental constituents are constraint to operate within certain rules. So you say that, you know an electron can do this; an electron cannot do this and atom can do this or cannot do this, an atom will stay within certain limits for some purpose whatever so there are some set of rules that you will place that set of rules then forms that model.

You are saying that in in your material the atoms and the electrons and the nuclei or whatever is relevant to you for that purpose are operating within a certain set of rules. This complete package of rules then becomes the model and what you get out of it is what would happen, if the material actually did behave the way yours you are suggested. So it is actually when you say you are modeling a material really the thing, that you are doing is you are putting a set of rules on the material and then trying to see what would happen, if indeed those rules were valid. So this concept is what is called modeling a material.

Now, these rules in some sense, these rules may be arbitrary because you may actually start from some at first you do not have any particular starting point. So, you you look at whatever is known about materials or whatever is understood so for about materials and based on that, you put some set of rules. So they are not completely arbitrary, but at the same time, you have the freedom because it is a it is a material model and you are developing the model, you have the freedom to select those set of rules that you wish to enforce on the material. So, at this point a model then is a theoretical process, so you are the actually theoretically putting down these rules and we based on our understanding of the signs of how material constituents behave. We then enforce these rules on those material constituents; in in other words we enforce these rules on atoms and electrons. So, what would happen is we will now see then based on those rules being employed on being enforced an a atoms electrons and so on.

We find that a collection of those atoms, collection of those electrons will will have to behave in a certain way, so that is how the model develops. So, we have done up to this stage, so the significance is that we now have a feel for what properties of materials will display, if in fact our original rules were correct, so up to now this is only a theoretical process. So, we we choose some rules, which were at our discretion based on our understanding of the science, based also on simplicity, we would like to start with simplest set of rules, we can enforce we enforce those rules on electrons and atoms and so on.

And then, we we we say that, now that few electrons behave like this large collection of electrons behave like this and so on, what would a material a solid object that is given to you consisting of electrons, atoms, nuclei and so on, what would that solid object actually demonstrate, in terms of material properties based on the fact that you have enforce some rules on it. So, this is the end result of your model, so what happens now is for you to see, for us to gain understanding of the material. We would like to see how correct our models, so that is the stage that we like to get into, so for this we have to understand the relationship between theory and experiment.

Now, when you talk of theory, you have a lot of freedom. So you have some rules, but you also have some freedom, rules are in in the sense that based on our understanding of the current science, we understand that certain principles are not violated by nature and so on. So, we often when we set up rules for a material, we do not arbitrarily throwing rules, we putting rules that we are reasonably sure that constituents of the material will have to adhere too. So that is what we start with, but even there we have a range of such rules, so we start with whatever is the simplest.

Now, experimental thing is something different, experimental thing is the process of experimentation is that, if you actually have a solid object with you or something that you some sample that you have with you. And you physically subject it to some conditions and on that basis you obtain some data. So, the general relationship between theory and a experiment is something like this. In general, if you have experimental data, it is the it is the problem of the theory to figure out how to explain that experimental data. So, in general the assumption is that, if you have got your experimental conditions right and you have conducted an experiment correctly.

In other words, if you think a temperature is such and such in fact the temperature is such and such, if you have such controls and you conduct an experimental experiment correctly and people are satisfied that you have conducted the experiment correctly. Then it is the business of the theory to figure out, how to answer the experimental data. It is never a case, where the theory predict something and even though it is in complete conflict with the experimental data. You would be required to accept the theory, it never works that way, it always work such that the theory may predict something that has never been seen before.

So, in which case you may need to come up with a new experiment to see whether or not the theory's prediction actually occurs, but in general if if the theory is dealing with an experimental situation that has already been carried out. So, in other words you come up with a theory to deal with an experiment that has already been conducted, then as long as the experiment has been conducted correctly. The theory has to find a way to fit the experimental results, it is not the other way wrong, it is not that the theory somehow does not match and you have to readjust your experiment. So, in this sense the experiments are supreme, even in the instant that you come up with a new theory that predicts something totally new, predict something that has never been seen before, under conditions that have never been created before.

Again, if the experimentalists can actually find a way to create those conditions, if they see a result that is consistent with the theory then they are validating the theory. On the other hand, if the experimental results actually still do not match what the theory predicts then it is a theory's business to find out why. So, this is the general relationship between theory versus experiment. So, what is it is relevance to the course that we are going to do. In our course for us to gain understanding between the science and the engineering of materials, what we will do is we will develop models in other words theoretical models for materials.

And then we will develop that model for enough, that we are able to make some predictions about material properties. At this point, we are making predictions on material properties, where such experiments have already been conducted. As I mentioned to you, if an experiment has already been conducted and if it has been conducted correctly, then the results of the experiment are in fact supreme in that sense. So, we will build a theory, we will see how well it matches the experimental results. If it matches the experimental results very well then the theory has adequately explained experimental results.

Then the model which is based on this theory model of that material is correct, that is the general approach that we will take, what we will find is that we will of course start with these simplest of models, when we say simplest the the simplicity comes from the kinds of rules we place on those constituents, we will place less tringent rules on the constituents the atoms and electrons and build the model. And we will see how will the model predicts the experimental results, what we will often find is that the initial models that we generate will in fact predict certain number of properties correctly. Certain number of properties of the material will be predicted correctly. Certain aspects of the material properties these models will fail to predict.

So, our procedure as as you may now figured out is then to go back to that theoretical model that we made and see what are those conditions that we can enhance that we can change and see if these new set of conditions a hence therefore, a new model of the material is now able to not only predict the all those things that the previous model predicted correctly. In addition it is also able to correctly predict the few things that the previous model was not able to predict correctly. So, this is the way we we proceed, so a model is good as long as it is able to match experimental data, that is the basic idea and we can keep improving models till we get more and more of the experimental data to match. So, now the question therefore, again little overriding question is, what is the level of when should we stop this process, can this go on indefinitely right.

Now, we know certain set of properties of materials, if you find a new property that the that the existing best model does not predict that does that mean, we should abandon all these models, the... So that is a very valid question to ask, because even in even in these few models that you will see, we we would like to know if you should abandon the earlier models, in a strict scientific sense yes you need to abandon all your older models, you need to only get the best model that can actually meet all the requirements of predicting all material properties and so on.

But from a more practical perspective it is often considered sufficient, if within the limits of the model the prediction is acceptable and therefore you can use the prediction, by that I mean, if a model can predict say the electronic properties of a material within a certain range of temperature, just for an example, but is not able to make the prediction beyond a certain range of temperature. Then as long as your experimental work is within that range of temperature it is acceptable, in fact to use that model, in fact you will often find in published literature there are empherical models and so on, where people do not have a very good feel for the science behind why that model works, but still that model actually makes the prediction.

So, in other words, if for the experimental conditions choosen, if you choose any one of the set of conditions, it will make a prediction on on the material property, if you run the experiment, it will match the prediction. So, within that limit, if as long as you recognize the limits of that model, if you stay within limits of that model, it is ok to use that model. So, in in that sense when we look at various models and we look at models that are simple, but fail in some which and theref succeed in some ways and failed in some ways. It is not immediately necessary for us to completely condemn the model and and abandon it, we simply recognize that this model operates within these limits.

The next model, which is which we consider is better operates under a larger set of limits, so based on our requirement; we can choose a model of adequate sophistication, which will meet our requirements. So that, we within the range that we are actually operating a it will work perfectly fine. So, that is the relationship between all the models and the theory and how we would like to use it and the experiments that we would conduct with them.

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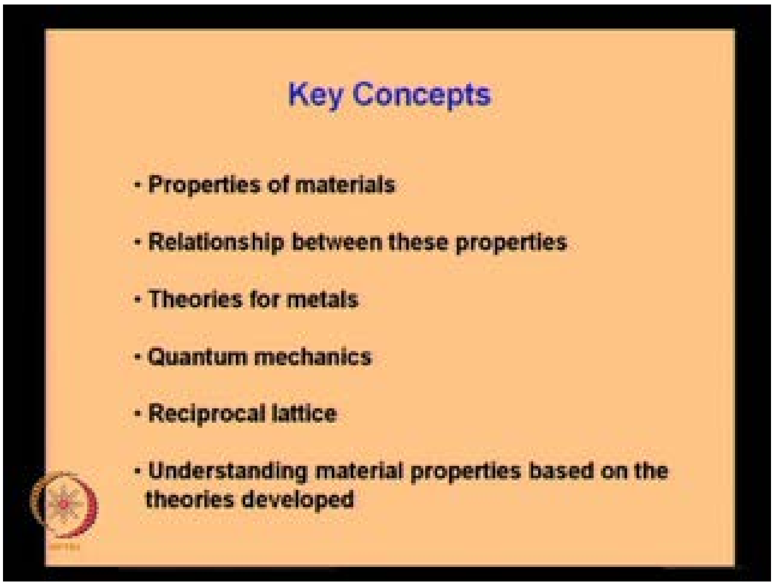

So in this course, as I mentioned we will look at models of materials and that is why we discuss that in such detail. The general key concepts that we will sort of cover in this course are properties of materials, so that is where we will start, so we will at least understand some, we will not look at all properties, but we will look at some specific properties, which are of interest with respect to the kinds of models, we will develop in this course. We will look at the relationship between those properties, this is important because as I mentioned for our purposes the experimental data is what is supreme, so when we look at properties of materials, these are properties that have actually been measured experimentally, when we look at relationships between those properties again that is something that has been measured and demonstrated and recorded experimentally.

So this, then forms the sort of the supreme set of information, that we have to somehow match with our theories, once we understand some of these material properties and so on. We will look at theories, in this case I have mentioned it as theory of metals, but it is theory of materials in general, we will look at theories we will look at theories that can be used to attempt to explain experimental data and we will look at a hierarchy of theories. We will look at these simplest that we can develop, we will look at more sophisticated theories and we will go back and match it against this experimental data that we have previously become familiar with. We will find that in some cases the theories will match, some cases the theories will fail and so on. And the theories will need to be enhanced an improve or refined.

In this context, one of the fundamental set of rules, that we will have to employ on our materials is are the rules of quantum mechanics. So, to some degree in our course, in fact very significant degree in our course, we will look at quantum mechanics. So in this course, I will spend some time looking at the basis of quantum mechanics and at least try to understand, why we we often find that a lot of people have a lot of difficulty in understanding quantum mechanics. We will at least try to understand, why there is a difficulty in understanding quantum mechanics, we will look at the background of quantum mechanics from where it came, how it came about and what kind of rules have come out of it, that we now consider you know quite sacrosite, but still they are the people still study it great detail too see if there are better theories and so on.

But we would look at quantum mechanics, because it seems to work for a wide range of conditions. So, we will look at it, we will see how best we can familiarize ourselves with it, how best we can handle the difficulty in becoming comfortable with quantum mechanics, at least understand why we are finding a difficult to understand quantum mechanics. So, we will spend some considerable amount of time in quantum mechanics or on quantum mechanics. And we will also employ quantum mechanics to refine our models and we will see how much of an improvement we get when we employ quantum mechanics on material models.

The next topic that we will spend fair bit of time on reciprocal lattice, this is independent construct that we will make, we will look at what is a reciprocal lattice, how it comes about, what sort of rules we can place are used to creative, we will see how it relates to what is called real lattice. So, this is this relationship we will understand and and then we will extend it to the material, this is as an independent entity we will learn this reciprocal lattice concept, then we will extend it back to the material. The reason we will do this is that we would need a combination of quantum mechanics and reciprocal lattice to actually make very good predictions about material properties. So this is why we will spend some time and develop this concept.

So our final goal would be to understand the material properties based on the theories developed and so all of those things that we will mention till that I have mention till now, the properties, the relationship between properties, the theories, the quantum mechanics and the reciprocal lattice. All of these will be brought together and we will now see, that a wide range of material properties are explainable on this basis, when I talk of material properties. In general, we will our focus will be more on electronic properties and such, we will focus less on mechanical properties, more on electronic properties. We will look at the electrical properties, optical properties, magnetic properties and so on. So that is the our tendency will be towards those, but that is the general gamate of our activity.

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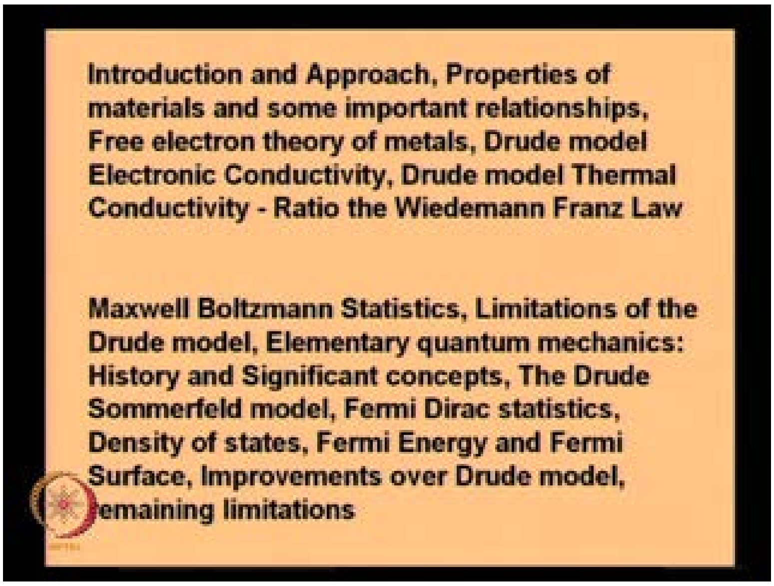

In terms of our actual topics that we will go over, we will look at properties of materials as I mentioned important relationships. One of the first theories we will develop will be this theory on called the free electron theory of metals, as I mentioned it will be one of the simpler theories, a simpler in from pearly the perspective of what rules we place on that theory. So we will start with simpler theory like that, and we will develop something called Drude model for electronic conductivity of the material. So, Drude model for the electronic conductivity of the material is something we develop. We will also develop a Drude model for the thermal conductivity of the material, Drude is then it is named after the person who created these models.

So, we will look at that, there is a ratio between the electronic property of a material and thermal property of a material and that is called the Wiedemann Franz law and we will see how our first, we will we will see that law as an independent entity as an experimental knowledge piece of knowledge that we will see, but we will also see how our very first theory is able to actually correctly predict the Wiedemann Franz law are how well it is able to predict the Wiedemnann Franz law. We will see what limits it has the theory has what sort of properties it is not able to predict and so on.

So, we will recognize that you know, here is a model that actually was generated using some rules which are not farfetched and at the same time it was able to actually make some good predictions and not able to make some predictions. So this level of development we will do, through this course we will also look at statistical mechanics, because that is a very inherent thought of how you extrapolate information from few electrons to a large collection of electrons to very, very large collection of atoms and electrons in a slove. This connection between you know the behaviour of a very small set of particles to a behaviour of a very large set of particles often requires us to use the tools of statistical mechanics.

We will use it on a few different occasions through this course. Our first use will be in the development of the Maxwell Boltzmann statistics, it will help us actually in addition we will that will help us actually understand some of the the early model that we will look at the free electron theory of metals. We will recognize the limits of the Drude model, which will then require us to look at quantum mechanics and therefore, we will look at elementary quantum mechanics. In this, as I mentioned I will start of by first looking at the history and significant concepts of quantum mechanics mainly to get a sol into a comfortable position from where we can utilize the tools that quantum mechanics gives us by fully at least becoming comfortable with what it is that we are uncomfortable with so to put it that way.

We will then enhance our model, the Drude model will be enhance to the Drude Sommerfeld model. Then we will look at the the next statistics set of statistics that we would be interested in, which is the Fermi Dirac statistics these are all named after people who created this body of information. We will look at something known as the density of states, which is the density of energy states that are available for various electrons to occupy and so on. There is a concept called the Fermi energy, which is again something that we will try and understand what is the Fermi energy, what how does it come about and how you could utilize it, what is it is significance and so on.

The Fermi energy is also related to other concepts such as the Fermi surface, the Fermi temperature and so on. So these relationships we will see, what they are what is the significance of it and so on. And we will improve the Drude model use and whatever in whatever way we can based on all of these things, we will also see that even at this stage even though we have done an initial attempt to put quantum mechanics into the system, there may be still some limitations that are remain to be overcome, so we will see if what else we can modify in the model to try and overcome those limitations.

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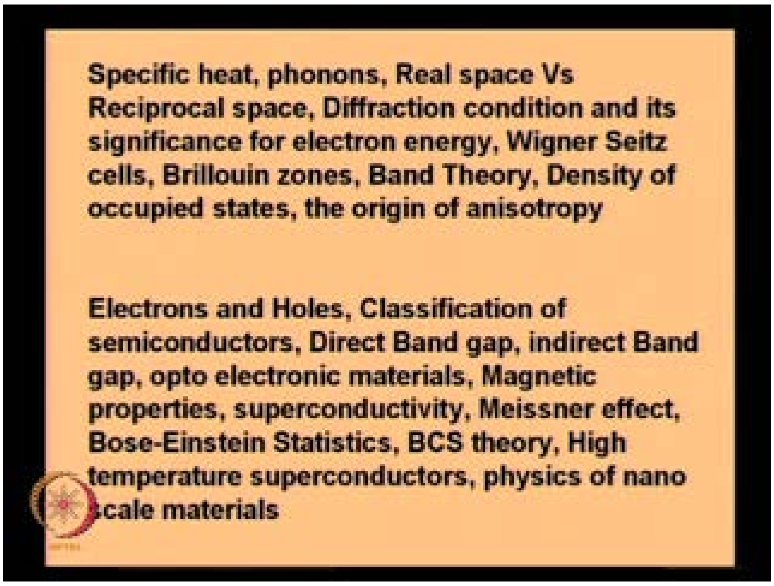

We will look a little bit at specific heat, we will look at phonons, which are lattice vibration equivalent of photons, so we will see what they are what is the relevance of them. We will look at the relationship between real space and reciprocal space, I mentioned reciprocal lattice that is associated with reciprocal space, we will try and see what is the relationship between real space and reciprocal space. We will look at diffraction as a concept and how what is the condition for diffraction and its significance for a electron energy, at this moment the kind of material that this course deals with is such that ever, so often we have to go a little bit on a tangent understand a concept separately and then try and re associated with the body of information that we have generated up and till that point.

So reciprocal lattice, reciprocal space and diffraction conditions, these are something that you would normally associate with material characterization course like X ray diffraction or electron diffraction. So, when we get into that section and I will alert you to this situation at that point also, it will appear to be a tangent from the normal material that we have been dealing with up and till that point. So, we will have to develop this information independently, but we will link it back to our original body of information by now having a larger model, which also incorporates some of these concepts.

At that point, you will understand why those concepts are necessary, so that is that is what you will see, so ever so often you will go on we will go on a tangent and it will be a necessary tangent, so that is why we will do that. so real space and reciprocal space diffraction conditions and its significance for electron energy levels is something we will look at, we will look at a construct that is called a Wigner Seitz cell and that will be related to another set of concepts that we called as Brillouin zones, we will have to get this for for us to actually get a more comprehensive model of the material.

If we have come this for we will now be able to understand Band theory often metals and materials, Band theory again a something that many of us are familiar with even from high school stage, but often it is just taken at phase value, you are just directly told that there is something called a conduction band, there something called a valance band, there something called a band gap. Often there is not enough theoretical background are understanding on how those come about, from where did a band come, why should there be a band and what is relationship between all of these bands and so on.

So, when we look at band theory, we will go one step more than what we have done up and till now, what you are familiar with up and till now, we will actually understand how those bands come about and what is the significance of it and that will be very integrately related to all that information and theory that we have developed up and till up and till that point. It includes everything from up to the drill one zones that we would have done, so all the Fermi energy drill one zones all of those information, it seems like separate the names up and till this point will all connect up, when we look at the Band theory and we will understand anisotropy in materials and so on.

We will then look at electrons and holes, classification of semi conductors, we will look at something called direct band gaps semiconductor, indirect band gaps semiconductor and we will also look at opto electronic materials. These are all technical terms, which a typical undergraduate student may be very unfamiliar with, but that is the purpose of this course, when you are done with this course. I believe you become very familiar with these concepts, you become very comfortable with the concepts, you will understand where they come from and how best utilize them. So, that is the intent of this course and that is the thrust of this course.

We will look at magnetic properties and in relationship between the magnetic properties and the electronic properties, we will try and understand superconductivity, so super conductivity is again a concept is a phenomenon actually that has been known now for a few several decades. So, we will now understand the theories that help us explain superconductivity. In particular, we will look at something called the BCS theory, which is the theory that is considered to be the best known theory for superconductivity.

We will look at something called the Meissner effect, which is very unique to super conductivity, even now as the name suggest super conductivity may appear as a very good conduct material that is a very good conductor is a super conductor may be the first impression that the term conveys to you, but it is much more than that, there is something more specific about a super conductor that are which which is what is required to be demonstrated by a material before it can be called a super conductor. And that is the Meissner effect, we will look at that I I mention that we look at statistical mechanics in at different stages in this course.

So, one more statistical mechanic activity that we will do is to look at the Bose-Einstein statistics, so and do the degree that it associates itself with various character phenomena that we have seen of till now. And we will also briefly look at the high temperature super conductors and we will finally, and you will see at this stage that you know even as of today there is no good theory for high temperature super conductivity. So, even with all the sophistication that we develop, you can see that even now there are materials, material properties that you can actually measure in a lab for which there is no convincing theory available to explain.

So, but we are still able to do a a lot of other things that is and that is exactly the point that I was trying to make earlier, which is that theories have limits as long as, we are within those limits we can use those theories. So, the best theories available for super conductivity fail to explain high temperature super conductivity, but still it is usable for other conditions. And we will finally, finish off with look at the physics of the nano scale materials, which will again pull together a lot of these concepts and help you become more comfortable with how these concepts relate to something that you can actually physically see measure and associate with.

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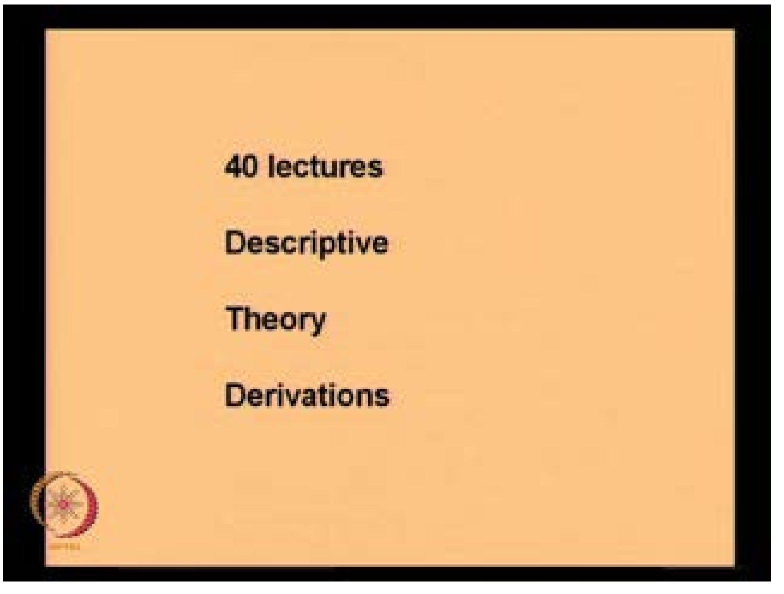

So, overall if you look at it, this course will consists of about forty lectures. So, through this lectures, we will cover all of these topics, as I mentioned the body of information that we are trying to handle here, is at times may look un wieldy, but we are trying to find an approach systematic approach by which we can actually make sense of this wide range of information that is available to us, are that we have to work with. In this context, in these forty lectures, we will you will find that there are some which are purely descripted in in the way in which the lecture is presented. The kind of material that we discuss and we look at and so there will be some which are purely descriptive, there will be some which are which focus entirely on the theory theory associated with with some material property and so on.

So, we will spend a fair bit of time on the theory in some lectures, where there there may not be much descriptive material and there will also be fairly mathematical curve. We look at derivations, derivations that help us put a mathematical framework for that theory. So, theory would be just still a description that we still put on in sentences that we can just follow, but there will also be derivations in some may be simple derivations, some may be very detailed derivations and so on. So, our lectures will be like that there will be a variety in our lectures and therefore, I suggest you that as and when necessary please look up this very first class of material, that we are that we have just come through to help you understand the fact that, these are all related.

So, we will have lectures which are only descriptive, only theory, only derivations, but as we progress over a period of several lectures, all of the material will connect up to each other. So, and as I mentioned ever so often has necessary, we will take a tangent, but that will be a necessary tangent, we will develop some body of information independently and we will connect it up to the rest of the information. I am highlighting this upfront because, as I mentioned right at the beginning. The intent is to make this course completely self contained. So that, at any stage you can actually look through this body of forty lectures and have a very good sense of, where this material comes from, how these different concepts relate to each other, what are these concepts and how they relate to each other and what is it that you can extrapolate from it.

So therefore, we are we will be using this approach, I will show you throughout the course, I will give you additional material that you can look at and so on, but it will still be such that the material we are looking at here is self contained. So, that will be an underline idea that I will try and enforce through this lectures and I believe it will be very beneficial, because it ensures continuity. And in my opinion for the kind of material, that we are going to discuss in this course continuity would be very fundamental necessity. If you have that continuity, it will much easier to follow.

And it will help you deal with some of the uncertainties that you feel, when you pick up book on this this kind of a topic. There are very good solid state books, introduction to solid state physics books that are available, excellent books very technically correct books and so on, but usually a typical engineer might face difficulties following those books. So, this lecture series will try and get you to a position where you can read that book and and feel comfortable, because there is enough framework that you can associate with all of that material that you see in those books. So, that is the level that I hope to bring each of you up to so that, you become very comfortable with any of these material that is presented.

And which you encounter anywhere else, we we will also try and link you up with I will try and show you, where in the literature some of this material appears and therefore, again make you more comfortable with what you might see in the literature. I would like to finish off this first lecture by highlighting one more aspect of the material that we will look at in this course, because I think it will again put in perspective, what I said that we are trying to do and why is it you may fease, you may feel difficulties at various stages.

And my insistence, that will try and ensure continuity over this entire material, throughout this material we will look at concepts and phenomena and so on, which are so significant that many of them have resulted in people associated with that concept or phenomenon or theory receiving noble prizes. So, derivations that we will do are derivations that let people to get noble prizes. So, these are considered very fundamental, very significant aspects of the science of as we understand it today of our materials. So these are all each of these really pushed the envelope of our understanding of material science and engineering.

So, it is therefore, not surprising that the first time, we encounter these materials, this kind of information it is not you you recognize that there is some difficulty in understanding it and following it and so on. But still, there is enough and therefore, it is not something that you need to get worried about, we would still go through this material in such a way that, even though it is of that quality of information. It is still something that every student, who follows this material carefully will actually be be able to understand.

So, we will make those derivatives, the derivations we will follow those tangents as and when necessary to ensure that even though, so many of those derivations, so many of those concepts, so many of the names that you will hear throughout this course. Are people, who are noble prize winners, whose works whose work has lead to noble prizes and so on, despite all that, it is still some material that you become very comfortable with and it is still some material that you can utilize extend and so on, and I hope as I said right at the beginning, this this is something that will be beneficial to you regardless of whether you become a material scientist or a material engineer. Ultimately as a professional, it is in your hands to decide, how much you would like to utilize your own background information.

So, you become more valuable, if you really take advantage of that entire body of information that you have gained, body of knowledge that you have gained, and then put it to use in your work place. So, so this is going to be a very strong supportive body of information for you, so it will be to your benefit to understand it well, and to utilize it well. So, with this we will conclude our first class, we will proceed with various other topics that I have already outlined, and as I said before I encourage you to look up this material ever so often. So that you understand the layout of the course, and where we are headed in this course at any given time. Thank you. .