Solid State Physics
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Lecture – 01
Atom to Solid Structure

Welcome to Solid State Physics; a course for undergraduate students of science and engineering.

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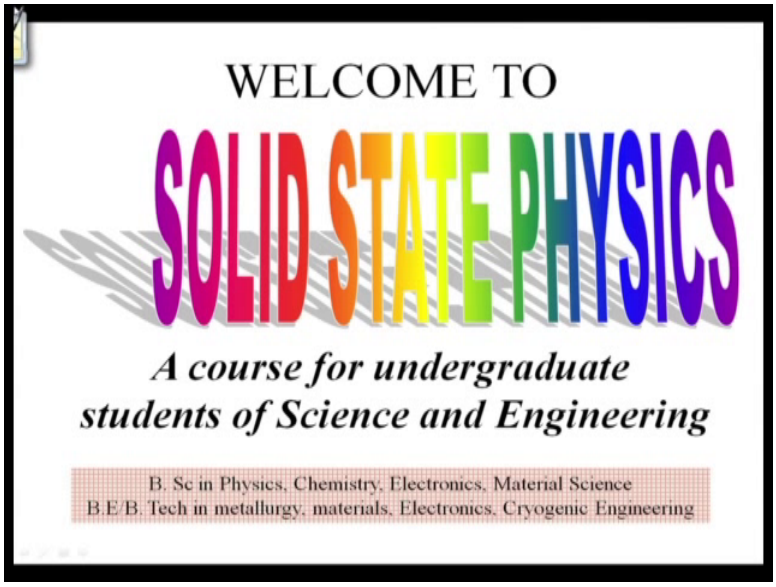

So, this course is suitable for the degree B.Sc degree in Physics, Chemistry, Electronics, Material Science, also for B.E and B.Tech for metallurgy, material, Electronics, Cryogenic Engineering. So, I am Doctor Amal Kumar Das from Department of Physics IIT, Kharagpur.

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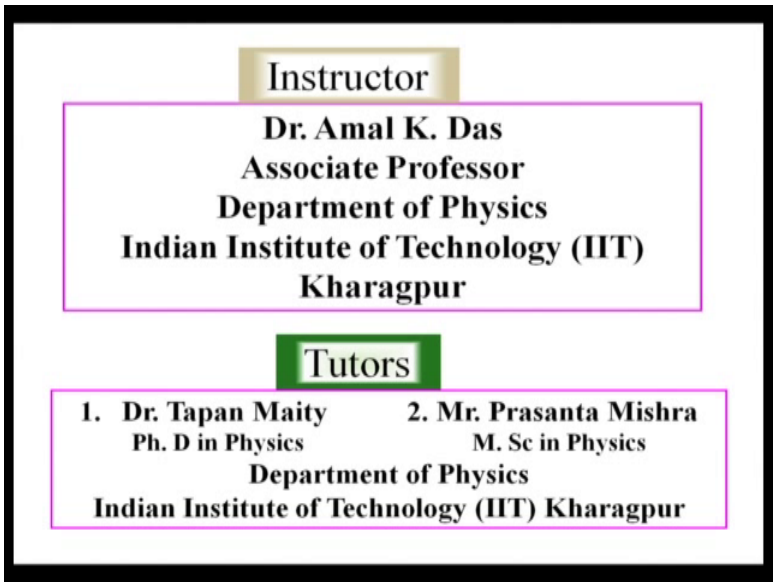

And we have 2 Tutors for this course Doctor Tapan Maity and Mister Prasanta Mishra from Department of Physics IIT Kharagpur. Course Plan Details are the following. So, this is 12 week course and we will try to cover the following contents.

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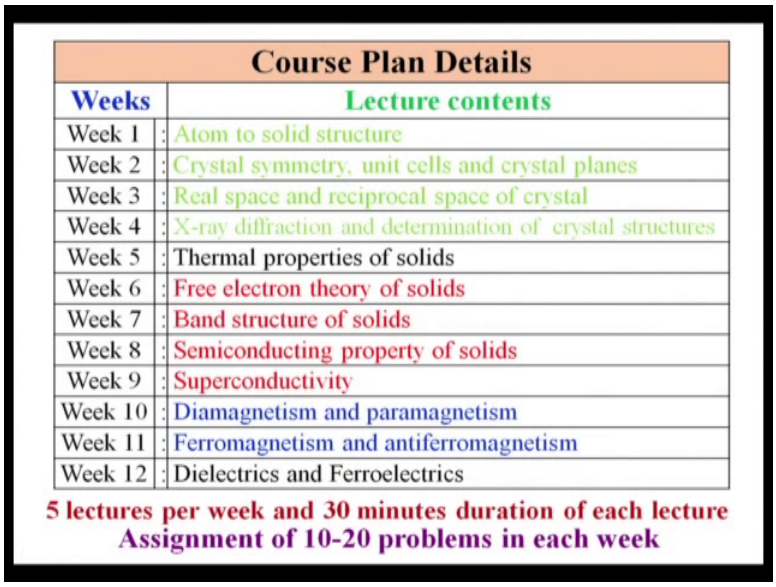

Say in first week we will discuss about Atom and from atom to how solid state structures are formed. So, that we will discuss and then Crystal Symmetry, unit cell crystal planes, Real space reciprocal space of crystal, and then we will discuss how crystal structures are determined experimentally using the X-ray diffraction, then after that we will discuss

different properties of solids such as this thermal properties of solids, electrical properties of solids, magnetic properties of solids, and dielectric properties of solids.

In electrical properties of solids there we will cover the Free electron theory of solids, then structure of solid, Super conducting property of the solids, also Semi Conductivity property of solids in magnetic property we will cover this Diamagnetism and paramagnetism, Ferromagnetism and anti-ferromagnetism and then we will discuss Dielectric and ferroelectric properties of solids.

Basically 5 lectures per week and 30 minutes duration for each lecture assignment of 10 to 20 problems in each week will be given.

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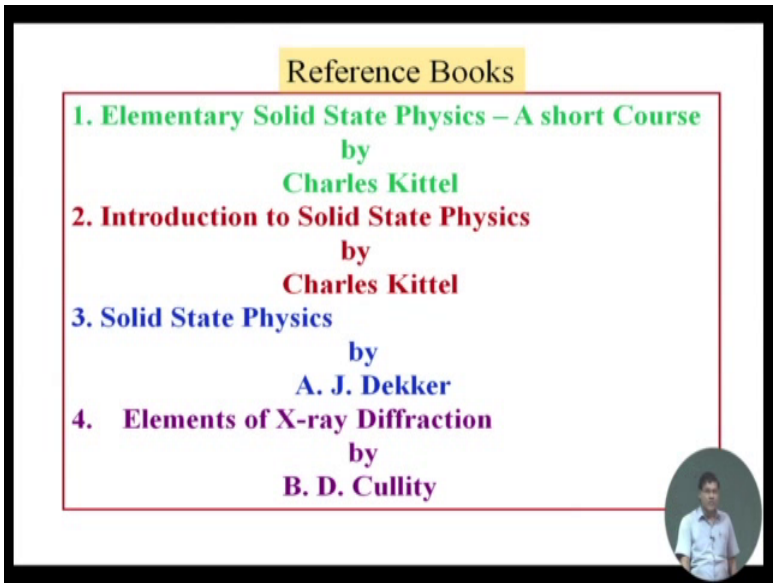

So, 1 can follow the Reference Books the Elementary Solid State Physics by Charles Kittel and also another book main book of Charles Kittel of the Solid State Physics, Solid State Physics by A.J. Dekker and for crystal diffraction. So, you 1 can follow the books Elementary of X-ray Diffraction by B. D. Cullity mainly first 2 3 chapters will be useful for this course of this book elements of X-ray diffraction.

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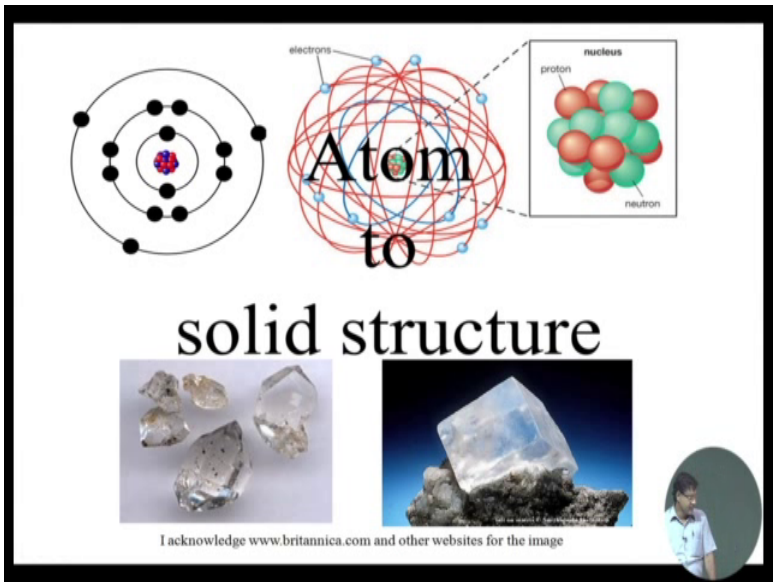

Let us come to our subject that we will start from Atoms and see how solid structure is formed. So, Atom have electronic structures say atom have basically 2 parts 1 is nucleus and other 1 is orbits all electrons are revolving see you know that nucleus is having photon and Neutron Photon have positive charge and nuclear number of electrons are surrounded the nucleus. So, number of electrons and number of photons are same in a atoms. So, thus atom is a Neutral.

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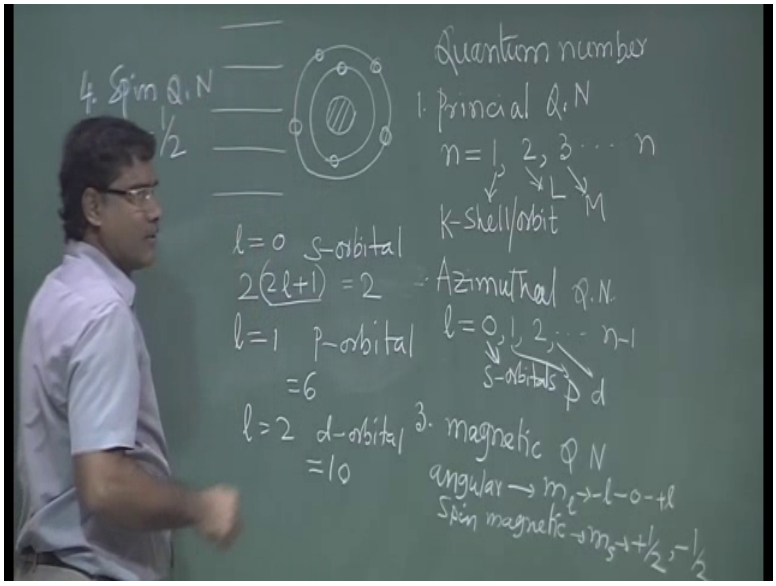

So, these are well know to you now here how these electrons are arranged on orbits. So, that following some principal electrons is distributed among the orbits. So, basically for that we use the quantum number. So, what are those quantum numbers you are you are quite familiar 1 is Principal Quantum Number. So, that is n; n can take value 1, 2, 3 etcetera so this basically represent the of cell or orbits.

So, this n equal to 1 is basically K-Shell or K orbit right and then 2 K that is the a land then this t M n etcetera right. Now for each principal quantum number for each n now it has sub shell or orbitals so that is represented by another quantum number. So, all basically Azimuthal Quantum Number so that is represented by l for angular quantum number also we tell. So, that is l so l can take values 0, 1, 2 up to n minus 1 so for a particular n value so we have n number of Azimuthal Quantum Number.

So, it so for each Principal Quantum Number we have n number of Azimuthal Quantum Number so this l equal to 0 it represents an orbital that is called S-orbital or S sub shell. So, 1 it is basically P 2 basically d then f etcetera that way we represent these orbitals. Now for again for each orbital again there are again we can split using the another quantum number that is called magnetic quantum number.

So, this basically Angular Magnetic Quantum Number and Spin Magnetic Quantum Number say Angular Magnetic Quantum Number and Spin Magnetic Quantum Number. So, this 1 will represent by m l and this 1 will be represented by m s, basically m l if we take value from minus l to l to 0 to plus l and this m s that I will come later on introducing another quantum number that is spin quantum number. So, that is represented by S so is S can take only 1 value that is half and corresponding this spin magnetic contrary image? So, it can take value plus half and minus half.

So, these are the quantum number and this will tell us that in each cell or in each orbit how many electron we can put and in which way basically electron will be distributed among the energy levels. So, these are basically orbits represent the energy levels then again this orbits are splited into orbitals sub shells. So, their energy will be different when it will be different it depends on the situation. So, each cell basically or each orbit can accommodate 2 n square number of electrons. So, total number of in a orbit or shell it will be 2 n square.

So, when n equal to 1 when n equal to 1 so; that means, K-Shell or K orbit it can have plus n equal to 1. So, it can have 2 number of electrons l shell n equal to 2, it will have 8 number of electrons then M-Shell it will have 18 number of electrons. So, from quantum number itself we can we can distribute electrons in different orbits and then in sub orbit or sub shells how the electron are distributed that also we can find out like say when l equal to 0 when l equal to 0 .

So, basically that is S-orbital so it can have basically 2 l plus 1 number of electrons 2 l plus 1 number of electrons; that means, it will for l equal to 0 it will be 1, but that is not correct because each electron have again spin each electron have spin and that 2 l plus 1 at it has come basically from that magnetic quantum number, that is from angular magnetic quantum number, and this for spin magnetic quantum number for each spin each electron can have 2 2 orientation either spin or spin down.

So, for that for each electron it will have 2 steps so you have to multiply with 2. So, then it will be for l equal to 0 it will be 2. So, S-orbital can have 2 electrons similarly you can see for l equal to 1 it is P-orbitals. So, it can it can have l equal to 1 so it can have P can have 6 electrons P can 6 electron d can have 10 electron d is for S equal to 2 so 4510 electron for b l equal to 2 d-orbital.

So, it can have 10 electron similarly for f orbitals it can have 14 electrons right. So, from this quantum number we can easily distributed the electrons in different orbits orbitals and this orbit orbitals basically it is represent that is that the energy levels. So, generally energy levels we draw using the straight line. So, this way we also represent the energy levels other way also 1 can represent the energy levels.

So, in atoms how electrons are distributed in which orbit they are sitting or they are revolving; how many number of electrons are in outer most shell or orbitals or orbits. So, these are very important because this arrangement of electron decide the properties of atom and aggregation of these atoms is basically forms the matter. So, depending on these on the electronic distribution it decide the properties of the matter. So, that is way it is a it is very important to know how electrons are distributed in the atom, and also you see this when electrons are revolving they are they have the angular momentum you know, they have the angular momentum and when charge particals are revolving in a closed path. So, 1 can tell that current is flowing in a closed path.

So, as if current is flowing in orbit now when current is flowing in a closed path. So, it is it is equivalent to a magnetic moment. So, it shows the magnetic property. So, due to the electron revolving in an orbit in a closed path so it will help the magnetic property also. So, that will tell the magnetic moment so as you know the magnetic moment for the current in a closed path that 1 can 1 can write say magnetic moment mu it is basically i A i is the current flowing in a closed path and A is the area of the of the of the closed path not closed path area covered by this closed path.

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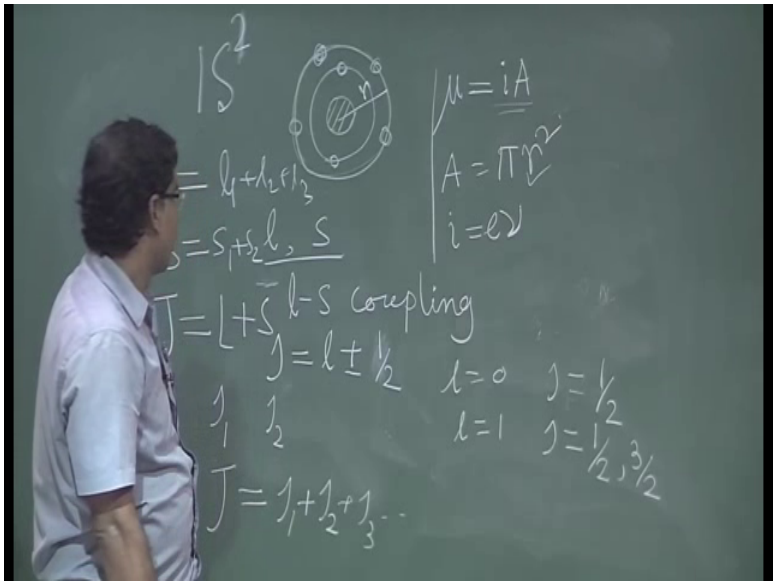

So, if you know the radius of the closed path circular path. So, this area will be pi r square and electronic charge of electron is e, now it is revolving if you know the frequency of this of this rotation then e that frequency is nu, then that will be basically current. So, nu is nothing, but this in per second how many times it is revolving. So, if you just look at the point then how many times these electrons are passing through the point in 1 seconds. So, that is basically current charge passing through a point or unit time per second so that is current.

So, basically you can find out the magnetic moment of these electrons in a particular orbit. So, magnetic moment of electron in different orbits will be the different will be different because it depends on the radius of the orbit. So, due to the orbital motion of the electron you will get the magnetic moment also, you will get the magnetic moment for spin angular momentum also, what about the angular momentum is there you will get

magnetic moment. So, for spin angular momentum also you will get magnetic moment. So, for orbital motion as well as spinning motion you will electron will have the magnetic moment. So, total magnetic moment will be the sum of these 2 n angular momentum or 2 magnetic moment.

So, electron have angular magnetic moment for angular motion as well as is it has spinning motion. So, that we represent by l and S. So, both are angular momentum. So, whether this 2 angular momentum are independent they do not bother each other or they have some they talk to each other or they are means they are coupled. Actually they are coupled they are coupled. So, that is called l S coupling that is called l S coupling and that l S coupling because of l S coupling 1 can get resultant angular momentum total angular momentum.

So, that is represented by J that is represented by J. So, for a electron the J is can take value l plus minus S and S is half for a single electron in a atom a c is half. So, J will for a particular electron whether it is at S orbit or it is P orbit or d orbit depending on that it will have total angular momentum J.

So, when l equal to 0 when l equal to 0 J is half it cannot be minus half. So, J is half when l equal to 1; that means, electron in is in p orbitals. So, this J value will be J value will be half and 3 by 2. So, 1 can find out the angular momentum 1 can find out the angular total angular momentum for each electron, now in a atom there are not 1 electron there may be there must be more than 1 of electrons.

So, only in case of hydrogen atom it has 1 electron it has 1 electron. So, where it will stay you know in the hydrogen atom 1 electron where it can stay principal quantum number 1 and this S is the orbitals. So, 1 electron can stay here for helium atom for helium atom 2 electron. So, S orbit can have can have can accommodate 2 electron. So, we can write 1 S 2. So, similar way 1 can place electrons and 1 can find out the total angular momentum for each electron for each electron, and now when more than 1 electrons in a atom now each electron have quantum number not quantum number angular angular momentum. So, total angular momentum for that atom how 1 can find out. So, 2 ways 1 can find out first 1 can find out the resultant angular momentum capital L.

So, that is basically l 1 plus l 2 plus l 3 etcetera that way 1 can find out. So, for these basically we use the vector model of atom to find out the total angular momentum and then similarly total spin angular momentum 1 can find out S. So, that is S 1 plus S 2 plus S 3. So, usually vector model so capital L it will not be 1 value it will be it will have many values similarly S will have many values. So, after finding out total l and total S, then l S coupling that will give total J so again using vector model 1 can find out l l plus S again j will have many value using vector model.

So, this way 1 can find out other way 1 can find out J 1, J 2, J 3 for each electron and then 1 can find out the total J for the atoms. So, that will again vector l addition. So, it will have many values J will have many values. So, these are very important to find out the find out the magnetic moment of that atoms and 1 can. So, whatever we told that that electron will sit in that orbit which orbit. So, that basically we are telling that about the ground state of the atom.

So, ground state of the atom electron can go to the higher level energy level also higher orbits also, but that will be excited state. So, this is the arrangement of electrons in atom and their quantum number of the of the atoms and these are very useful this will be very useful for our this course. So, this is the; you are knowing things, but I just remind you and then before going to the to the to the real topics.

Thank you very much.