namaste this is hc verma from iit kanpur and i will be giving you a series of lectures on semiconductors and when i say conductor it is the electrical conduction that i mean and you all know that metals are said to be good conductors all our wirings in houses or when you make a circuit on your table you use connecting wires and all these wires have mostly copper in it which is a metal and a very good conductor and we use these good conductors because they easily conduct electricity and the power loss is is small if i use aluminium in some of the old fans etcetera they use aluminum coiling also but then lot of power is wasted because of this low conductivity of as compared to copper then we have another class which is insulator ah any any plastic or any rope or any spring these are insulators if i have a battery i cannot connect the bulb using ropes the bulb will not glow because the rope is not conducting electricity

so what is a semiconductor in between as the name indicates the conductivity is much smaller than the conductivity of the metals if you compare with copper the materials which are called semiconductors will have a conductivity some 10 to the power 11 times smaller than the copper then why should i use that lot of power waste tissue will be there if i am not preferring aluminum over copper why do i prefer this semiconductor whose conductivity is 10 to the power 11 times smaller but it is extremely extremely extremely useful component in circuits electronic circuits the entire modern life is revolving around semiconductors be it a mobile phone a digital camera a tablet a laptop desktop any kind of control system mangalyan and chandragyan all those electronic control systems they use this semiconductors also washing machine anywhere if you have to control something most of the time you will find that semiconductors are being used amplifier ah someone speaks from a distance a microphone is there and then amplifier and then it goes to loud speakers all those amplifier circuits they use semiconductors

so what is

so special about it having such a lower conductivity still it is

so much of useful there are many many things that make it useful and one thing is you can control the conductivity in semiconductors the conductivity is copper is got given i cannot do anything to it but by simple processing of materials i can control the conductivity of semiconductor and whenever someone gets some control to tune things lots of applications result and that is why this semiconductor is

so important nowadays leds are being popularized because they consume less power these leds are nothing but ah made of semiconductors only

so it is at the center of our life and it is very interesting to understand why semiconductors are

so different from conductors and insulators

so before going into semiconductors let us understand what the conductor is

so as you all know you must have read in your text book a metal is a good conductor because it has lot many free electrons

so this word free electrons what is this free what to what is that freedom that these electrons have in a copper wire or a metal block you have lot many free electrons they are free to move anywhere in this metal do they not interact with the nucleus are they not bound to any of the atom they are they are its not a free space its not in a vacuum that electrons are moving you do have all those nuclei other electrons in that system ions and these electrons as such are are bound to one or the other atom but they are bound by very weak interactions not weak interaction strong weak and gravitational electromagnet the strength of interaction is quite weak you know you have an atom which has a nucleus and then you have 1s 2s etcetera 2p some 2p 3s and all those things and then the electrons are bound to this but that strength of binding goes on decreasing as

you go for outer and outer orbits

so if you have a electron in this orbit at a quiet distance from the nucleus then the binding is weak

so in a conductor there are some electrons which are very weakly bound to the nucleus and are

so weakly bound that because of any kind of thermal interactions with other things at any temperature finite temperature all these things can get some energy from the crystal randomly interacting with each other some exchange of energy does take place and because of that it can just leave this atom but if it leaves this atom is not that now it is free some other atom is is is sitting here it also has its own ah orbits and orbitals and states and

so on

so it can just make a jump to that other one if it finds a place there

so it can easily change its position in the lattice that is true but it hops from this atom to that atom that atom to that atom because it is

so weakly bound

so that is the meaning of free electrons

so first approximation is fine that they are they are free almost free

so you can assume that there is nothing to stop there and only occasionally it gets scattered from this side and that side changes its speed and direction and

so on

so forth but if you go you have to go slightly deeper to understand semiconductors ok

so then this binding is very very important

so let me go little more in this in this context and see how these energy levels in a solid material like copper or in a semiconductor or an insulator how these energy levels behave in solids

so you must have gone through that hydrogen atom energy levels

so in hydrogen atom what happens you have a proton and then you have an electron and these interact and then you say that there are orbits and all those things essentially what it is that you have some particular states which we call quantum states ok which we call quantum states why quantum because these states if they change energy they change energy in finite steps

so quantums

so they are quantum states the one quantum state which has lowest energy let us draw a line to show that if it had some kind of state not actually circular ellipse some kind of state some kind of distribution around this proton the energy of that quantum state is is lowest and we draw a line here and in fact at this same energy there are two quantum states the electron can be in one state or the other state with the same energy and that is the lowest energy and we call them one s states then you have a jump a quantum jump and then you have eight another states with different kind of distributions and there the energy is 10.

2 electrons volt above this energy difference is 10.

2 electron volts nothing in between electron can be in one particular state or in some other state but the lowest available state has this energy and the next lowest has this energy which is 10.

2 e v above with some zero somewhere people say that this energy is minus 13.

6 e v and this energy is minus three point four e and similarly you have other states and here in fact you have eight quantum states at the same energies and you call them 2s and 2p

so the states have different kinds of distribution around the proton

so that is why the name separate names 2s and 2p this will have 2 quantum states and this will have 6 quantum states

so a total of 8 quantum states are here and

so on

so forth like that similarly if you go for other atoms you have energy levels let us start with sodium a very simple system a sodium atom ok

so a sodium atom how many electrons are there 11 ok 11 electrons and we say that the electrons are distributed in different these quantum states and the electronic configuration is written as 1 s 2 2 s 2 p 6 and 3 s 1.

so what is this you have one s quantum systems quantum states at some energy which is the lowest one

so you have one s then you have somewhere two s then somewhere two p then somewhere three s and

so on and three p and three d and four s and all those quantum states are there all s states will have two quantum states all p states will have six quantum states and a wonderful aspect of nature is no quantum state can contain two electrons either that state will be empty no electron is there to occupy that state or at best one electron can be there that is called poly exclusion principle and our nature is like that i can only say that much

so if there are 11 electrons to be accommodated then to have this lowest energy you have two electrons here two electrons here six electrons here and one electron here then there are other quantum states which are all empty this three s quantum there are two quantum states one contains an electron and other contains nothing

so this is that atom one atom now think of sodium vapor on streets street lights you might might have seen those yellow lights coming in that lamp posts they are sodium vapor lamp

so it contains sodium vapor which gives yellow light

so in a vapor you have a lot many sodium atoms but they are in a vapor state gas state

so the separation between them is quite large and interaction between one atom and other atom is very small negligible

so each atom independently will have one state two s state three s two p state three s state and

so on

so each of these atoms separately one atom is here one atom is there one atom is there you will have this one s state for each one you will have this two s state two p state and

so on three s state and all these uh one s states will be occupied by two electrons in this atom two electrons in this atom two electrons in this atom and

so on

so even if you have large number of atoms but not interacting with each other like in a gas very very weakly interacting you still have put pick up any electron either the energy will be this or the energy will be this or the energy will be this or the energy will be this if you have n atoms a total of n atoms and you know what is the order of this n you take any gas sample or any material sample which you can see which you can handle this number is going to be 10 to the power 20 21 22 and

so on is a large huge number remember

so at this energy you have two n electrons at this energy you have two n electrons at this energy you have six n electrons at this energy you have one n electrons and no more electron can ah go in this energy no electron can go in this energy in this energy here there is a freedom half the states are still available

so if this electron this 3s electron let us say this 3s electron here it

somehow it can talk to the neighbor and there also you have three s electron here one quantum state is empty here one quantum state is empty here and if they somehow ah mutual adjustments this electron can go here or this electron can go here or this electron can go here some kind of movement some kind of exchange is possible is possible although in atoms gas in gas state they are too far away from each other such interactions and such ah interactions are are not very likely but it is a possibility but one has electron no chance no chance all one of s quantum states are are filled now what happens when we cool this sodium gas and make it a solid solidium lump where the distance between the atoms is is now smaller and then the sodium atom and the neighbor sodium atom they start interacting and that affect this energy ok that affect this energy in hydrogen atom we say that the lowest is minus thirteen point six why next one is minus three point four y from where these numbers are coming these numbers are coming because you have a particular type of interaction between the nucleus proton and this electron

so that interaction decide that coulomb interaction coulomb attraction that decides that it will be minus thirteen point six and minus three point four and therefore and

so in sodium you have a nucleus of 11 protons and then you have these 11 electrons which are interacting with each other and all that interaction decides that what will be the energy of this what will be the energy of this what will be the energy of this and when atoms come closer its no more interaction of electron with the nucleus of 11 e charge and the other electrons among themselves it also interacts with the neighbors electron at least which which are in the outer orbits and since the interaction is changed these energies are also changed energy of the quantum states are also changed and can also happen that the for example all these two n states which are here at the same energy

so some of the quantum states the energy goes up some of the quantum states energy goes down because the atoms are also not fixed they are vibrating and

so the exact environment of one atom at any instant may not be the same as the environment of the other atom it is interacting with its neighbors that is interacting with its neighbors but then since things are not static this interaction here with the neighbors and that interaction there in with the neighbors could be slightly different and therefore some of the quantum states may go up some of the quantum states may go down and what you have a sharp line here all the two n one s states are at one single energy can spread out all these quantum states may not be at that same energy some spread can be there

so this one is and this one s may have different energies although one as its very close to that uh pro that nucleus and you have outer electrons then outer electrons the inner electrons are not affected much by these interactions only the outer electrons are affected ah significantly

so in principle yes but in practice you can still assume that all these energies remain here and similarly here here but here here the outer one here it can be a very very different story here it some of the quantum states have gone up some of the quantum states have gone down in a small energy gap a fraction of a e v how many of these are are there this n is some 10 to the power 20 21 22 etcetera

so these discrete states may not look discrete they will look almost continuous all energies are available but they are discrete you can count whether it is 10 to the power 22 or 23 or 24 whatever you can you can count but still since the originally it was just one single line everything was merged there and now it is spread in a very small fraction of electron volt or

so so it will look like a continuous thing look like this here the spread will be there but less here it will be still less here it will be almost negligible

so these are called energy bands and these are called energy gaps these are gaps energy gaps

so originally i drew two lines and there was a gap and now you have two bands and then the lowest of this band and then the highest of this band this difference is the energy gap

so in solids you have such energy bands separated by energy gaps now suppose i apply an electric field how is the current goes in a wire when you take a battery when you take a battery and you take some kind of a bulb or something some resistance and connect it here the bulb glows or if it is some kind of heater it becomes warm

so what happens how does the current go this when i connect everywhere in this material you set up an electric field e field ok you set up an electric field in the wire in the metal in electrostatics the electric field in a metal is always zero but this is not electrostatics the current is going

so you set up an electric field and once you set up an electric field that electric field exact force on these

so called free electrons if there is an electric field it will exert force on every electron right f is equal to q is valid

so it will exert force on all these two n electrons which are here these two n electrons which are here these six n electrons which are here and these one n electrons which are here it will exert force it will try to accelerate it it will try to ex ah exchange energy from the field the energy will be going to the electron and therefore if everything was normal the things were not ah such quantized then you apply a force there will be acceleration kinetic energy will increase simple classical mechanics but now think of this electron which is sitting here or think of this electron which is sitting here or think of this electron which is sitting here if if you think of that hydrogen atom once again this gap is 10 per 10.

2 e v suppose the electron is here and you offer this electron and energy of 2 electron volt it will not accept because if has it has to increase the energy minimum it can accept is this ten point two a v

so even if you apply a force even if you try to accelerate even if you try to give energy to this ah shine some photon do some anything it will not accept energy less than ten point two e v

so that is that is the story if this electric field if it tries to give energy to the one s electron or two s electron or two p electron cannot accept because all these quantum states are filled and the next quantum state is after this much of gap unless you give this much of energy for which normal batteries will fail to do that these electrons will remain there but these electrons you have empty quantum states

so if the if some electron is here and there is an empty state here suppose your electron is here and there is an empty state here that means in some of these large number of atoms there is an atom in which the 3s electron is at a slightly lower energy and there is a neighboring atom where a slightly higher energy state is empty that quantum state is empty it can make a jump because it can accept any small amount of energy and go from here to here ok

so these electrons will respond to the electric field and they will move according to that f equal to q e and of course that scattering from other ions and defects and those things will be there but at least these will respond to this electric field these will not these electrons are called free electrons or conduction electrons

so in a band if you have partially filled quantum states and partially empty quantum states those electrons can respond to the electric field and then they can cause current and that current will be related to the electric field through

this relation j equal to sigma e what is j j is your current density and what is current density you take a cross sectional area here in the wire you take a cross sectional area that cross sectional area is a the current is going i and

so j is i over a this is the magnitude and the direction is the direction of the current

so that is current density j and this sigma here is known as conductivity electrical conductivity

so that is how the conduction takes place now this band is known as conduction band why simple because only these electrons will respond to electric field for electrical conductions and therefore these this band itself is called conduction band in which the electrons can have freedom to move and the others are all valence bands we are not really concerned about the lower one but just lower to this conduction band this is interest this is important and this is known as valence band ok

so just the band just below that conduction band we will call them valence bell these are also valence bands but then these do not ah they are not important for discussing conduction

so we just show these two the valence band and the conduction bands here now think of magnesium in the periodic table after sodium you have magnesium z is equal to twelve

so in z is equal to twelve what will be like electronic configuration the electronic configuration will be one s two there are twelve that is twelve now

so two s two p six and then three s two what does this mean if you have this kind of diagram one is completely filled two s completely filled two p completely filled then three s completely filled

so if 3s is also completely filled and you apply an electric field what should happen there should be no conduction just like this these electrons cannot take part in conduction because all the quantum states are full

so if 3s is also completely filled you may expect that they will not respond to electric field and magnesium will be a bad conductor but it is not magnesium is also very good conductor of electricity why the next band three piece band there is no gap between three s and three p three s is completely field fine but then the structure of magnesium is such the atomic structure is such that you have one s you have two s you have two p you have three s you have three p and then when it all spreads out and this becomes three s band this becomes two p band and

so on you have three b band and that three b band is uh right here that three p band is right here it overlaps

so it is three s and three b this whole thing is now three s plus three p and therefore although it is completely filled but it does find empty space with little energy small energy if electric field tries to supply small energy they will accept because the quantum states are there

so for different atoms you have different kinds of energy bands this is one kind where you have a valence band then a gap and then the conduction band partially filled you have this kind where now this becomes the balance band this is completely filled although three s is completely filled but next three p is ah is overlapping

so you have a kind this is the conduction this whole thing becomes conduction band

so different kind of materials will have different kind of band structure energy band structure before we go to this silicon where is the silicon in periodic table carbon silicon

so carbon is z is equal to six silicon is z is equal to fourteen

so that is very interesting and the silicon is the key semiconductor material

most of our semiconductors are still centered around silicon and silicon is in a abundance in silicon if you z is equal to 14 if you think of that solid silicon or carbon there is another twist in the story

so for carbon or silicon where let us say silicon z is equal to 14.

so what will happen you will have a 1s 2 2 s 2 p 6 3 s 2 and p 2.

so if you have silicon atom as such you will have 3s 3s state and 3p state and this 3s will be completely filled this 3s is completely filled and three p is partially filled here you have two electrons and here also you have two electrons but the quantum state number of quantum states here is six number of quantum states its six only two are occupied and here the number of quantum states is two and both of them are occupied like this but when you have silicon crystal solid silicon no more you talk in terms of three s and three p the chemistry people say that three s and three p these orbitals get mixed up with each other and they call it sp3 orbitals sp3 hybridization

so the quantum state itself is now different you do not have a 3s quantum state you do not have a 3p quantum state the quantum state is sp3 like that you still have eight this two plus six is eight and here also you have eight quantum states

so the same 8 quantum states are now mixed up and you have a separate kinds of quantum states which you cannot say that this is 3s and this is 3p they are all sp three kind of quantum states and they occupy in this and what happens depending on the separation and all those things these eight n quantum states if you have n atoms in your silicon solid you have eight n quantum states you have many more below this uh and and above this you you have these are also quantum states you also have four s two and all that these are all empty you you do have these quantum states and these are all filled but i am talking of this one this one this part here these eight n quantum states and these eight n quantum states are now split in two parts ok

so you have these two parts like this this is your valance band this is your conduction band and then there is a gap and for silicon this gap is about 1 b silicon carbon also similar story qualitatively instead of this three s two p two it will be two s two p two z is equal to six

so two here and four here

so again you have that s two p two

so you have hybridization and similar splitting

so if you look at the carbon diamond you again have similar picture and here the gap is 6 eb and here the gap is 1 ev why i am

so much emphasizing on the gap and the magnitude of energy in the gap that decides the conduction property of semiconductors and these are semiconductors but whether it will conduct how much it will conduct should i put it in the insulator bracket or should i go into that conductor bracket or should i keep it in semiconductor that all is decided by this gap and this this number and this number is to be compared with a quantity which is written as boltzmann constant k times capital t ok

so this boltzmann constant k and multiplied by t this is the quantity with which this gap is to be compared where did you encounter this boltzmann constant in kinetic theory of gases you must have encountered this pv is equal to nrt and that r gas constant r is avogadro number times this k

so k is essentially that gas constant capital r divided by the avogadro number n a

so this is k and this is of course the temperature in absolute scale and for room temperature for about say 300 k this is around 0.

026 electron volt and why this kt because in a solid or in any material gas also the kind of energies which are available through these thermal interactions is of this order right the atoms are interacting with each other because of the temperature there is some vibrations and all those things and then through those thermal interactions the energies which can be exchanged between the atoms between the electrons outer electrons is of this order this order of energy is readily available someone is giving someone is taking and that is quantum that scale is is decided by this number k t which is for room temperature it is some 25 26 mil electron volts ok

so if you look for a particular interaction in which the energy exchange is 0. 5 electron volt much more than the average average is around 0. 026 e v i am looking for interactions where point five e v is exchanged the probability will be very small maybe i do not know what may be say one part in ten to the power ten but remember you have ten to the power 22 23 24 atoms also

so even this probability this is a small probability of 1 in 10 to the power 10 is huge is huge because you have large number of atoms

so there is a possibility that in some interactions the energy exchange is of the order of one e v what will happen if this is completely filled if this is completely filled and this is completely empty and through thermal interaction some electron gets energy and is promoted here then that electron is ready to if some electron goes here that electron is ready to respond to any small electric field and therefore this will start conducting contributing towards conduction and once the electron has gone out from the here the other electrons in this band they also get some kind of a comfort to move because there is an empty place and that can also respond to the electric field the electrons can go in that direction and some conduction can take place because of these electrons also

so this is the mechanism of conduction in

so called semiconductors if you have energy gaps

so that a sizable amount of sizable number of electrons have gone from the valence band to the conduction band then it becomes a semiconductor if the gap is very high 6 ev almost no chance of electrons crossing from here to here through thermal interactions this is insulator you apply whatever electric field nothing will happen but in these kind of things where the gap is one e v less than one e v in germanium it is less than one e v

so if these kind of materials are there then already there are some electrons here and if you apply electric field these electrons will respond and these vacancies these holes these empty positions broken bonds they also respond ah you can take an analogy an interesting analogy suppose you go to watch a movie and then there are blocks hundred rupees ticket and then two hundred rupees ticket now if it is a hundred rupees stick is ah block is completely filled these all persons will be seated no one can move even if your air conditioning on one particular wall is giving too cold air no one can move on the opposite side because every chair is filled although that 200 block 200 rupees block is empty but they are not allowed to go there because there is a huge gap of 100 rupees but somehow if someone is able to exchange his ticket and he moves to that other block then there are or a few people can do that then there are some empty chairs and then some movement is possible in this almost completely filled 100 rupees block also if there is some chair here and a cold air is coming here this person will suddenly jump here and if this person goes here and an empty chair is created here then this person will go here and

so on some movement will be there and of course the people who are in that 200 rupees block they will definitely ah run to the other side

so its some kind of of thing here

so that is how the electrical conduction takes place in semiconductors not only that conductivity is important ah for example here much less number of electrons are going here that is why it is semiconductors in a conductor like sodium or magnesium or copper you have by default ah a partially filled conduction band and therefore there is a huge number of electrons available for conduction here the number is less that is why it is semiconductor but then there are many other aspects one aspect is temperature what happens if you raise the temperature of a metallic wire a copper wire or a tungsten wire ah let us let us do an activity i have this filament bulb the filament is made with a tungsten and it is written here 100 watt it is a 100 watt bulb and 230 volts

so if you apply 230 volts the energy consumed will be 100 watt you can calculate resistance from here

so let us do that if voltage applied is 230 volts you know you have a bulb here you have a filament here and then you have you are applying this 230 volt here and some current goes here and power is 100 watt

so what is the resistance v square by p how much is that 230 into 230 and divided by hundred

so twenty three into twenty three how much is that twenty three into twenty three five to nine five two nine ohms everything in s i

so this will come in ohms

so if it is connected to 230 volts the filament will glow you will have light 100 watt bulb and at that times its resistance will be 529 ohm what is its resistance now at room temperature

so let us measure

so i will request marvaji to help me there is a multimeter you set it in the resistance measuring mode and just measure the resist touch the two and see that it is working yes it is working ok

so now touch the two terminals and the two ends of this filament bulb and see how much is the reading ok

so you see the display it is 43 43.
1 or 43.
2 is 43 ohm at room temperature

so a normal metal if you raise the temperature the resistance increases at room temperature at a room temperature this resistance is about 41 ohms but when the temperature goes high

so that it start giving light of 100 watt the resistance increases to 529 ohms now let me do one and one more experiment with this resistance varying with temperature and you see what happens now i will request ah mr arvind patak to help me

so here this is another bulb its led led bulb we use it for lighting and this led bulb i will be connecting to this battery

so is connecting this led bulb to the battery through a galvanometer you can see there is a small deflection in the galvanometer can you see this small deflection here next i have water here and a water heater here and a switch here

so let me heat this water

so this water is now heated i put it off and remove it and now what we will be doing is we will just put this led bulb inside this hot water

so that the temperature increases and now we are making the circuit and you see the deflection see the deflection

so the current has increased many fold by heating the current has increased manifold the resistance has gone down in case of tungsten in case of middle filament the resistance goes up on heating and here the resistance is going down on heating current is increasing

so semiconductor has a many different properties

so semiconductors not only the magnitude of the resistance or resistivity your conductivity the entire character is different the temperature dependence is opposite in fact this can be used to test whether a material is semi conducting or is conductor
 so let me summarize the key concepts that i had discussed today in this lecture the first thing we did was the energy levels in one atom i took an example of a hydrogen atom where the energies are discrete you say the lowest energy is minus thirteen point six e v and the next is minus three point four e ev and
 so on and these energy levels contain different quantum states at one energy you may have more than one quantum states and they are named as 1s 2s 2p and
 so on and each level that we are putting they have a definite number of electrons for example in all s
 so called s orbitals you will have two electrons all p orbitals you have six electrons and
 so on then ah the very important thing is that each quantum state can have a maximum of one electron which is poly exclusion principle a quantum state may be empty or it may contain one electron at best then we talked of the collection of atoms like a gas in which the interaction is minimal negligible in that case each atom has its own energy but since all atoms are identical they will have same energy levels and therefore the same energy levels will be applicable to this collection only thing that in each energy now you will have many more quantum states if it is let us say one s for one atom you have two quantum states but if there are capital n atoms in the system you will have 2 into capital n states here and similarly for all others
 so that is the difference then we came to solids and in this the outer electrons of an atom interacts significantly with its neighbors and therefore due to this interaction the energies are shifted and because of that what is a pure single energy that spreads into energy bands
 so that is how the bands are generated and then you have energy gap then we talked of conduction band and valence band
 so conduction band what is conduction band the lowest energy band which is not completely filled
 so if you have these are the energy bands you have some little spread here little sprayed here and
 so on
 so these are energy bands
 so look for the lowest energy bands which is not completely filled suppose these are all empty this is empty but here there are some electrons here there are some electrons
 so this ah this is not completely filled that means if this state is completely filled with the electrons we wont call it conduction band right
 so some empty states should be there then we call that as conduction band
 so lowest energy this is also empty this is also empty and here this is not completely filled it could be completely empty like this or it can have partially filled and partially empty
 so that we call conduction band and all this is i am talking at no thermal excitation its because of the structure because of the temperature of course some electrons can go to higher bands and that becomes non empty
 so i am not talking of that no thermal excitation then the band which is just below the conduction band which will be definitely completely filled that will be called balance band
 so this is definitely completely filled once again remember i am talking of because of the structure it is like this because of temperature you may have some of the electrons if they leave this completely filled valence band some

empty space will be created we talked about that at length
  so you have conduction band you have valence band and then you have gap this is that gap which is very important ok
  so the electrons in valence band they correspond to those which are strongly bonded to the atoms whereas electrons in conduction band correspond to those which are weakly bound to the atoms then we talked of this if the conduction band is partially empty you have lot of empty states around some of the you have lot of electrons also and lot of empty states also because of the structure itself that material will be a good conductor of electricity and if the conduction band is completely empty that is also possible then the material may be insulator or a semiconductor
  so if the band gap is small say less than three e v or
  so the material is semiconductor the butt is band gap that energy gap you know this is the conduction band the valence band and then this gap this gap band gap or energy gap if this gap is say 1 e b or 2 e v like that and if the gap is more if the gap is large larger than say three ev then at room temperature at least the conduction will be very very small and you call that insulator ok then we talked of temperature all that i gave all these key points where at say where no thermal excitation was considered and that means at a very very low temperature but if you are at a elevated temperature say room temperature which is around 300 k then you have thermal excitations thermal interactions and because of thermal interaction some electrons can go from valence band to conduction back and that leaves empty quantum states in the valence band right
  so if you have this valence band and if you have this conduction band and if some electron goes from here to here it populates some of the quantum states at the same time it makes some of these quantum states in this
  so far completely filled valence band it creates some empty states there which we call holes
  so that is the effect of temperature larger the temperature more electrons will be able to jump and then finally what happens if you apply an electric field
  so here in a semiconductor if you apply an electric field then the conduction electrons do find empty spaces empty states empty quantum states around that energy and therefore they can absorb energy from the electric field little bit energy whatever electric field can provide that electrons can accept and go to slightly higher quantum states which are available and therefore a drift is possible at the same time in the valence band also if there are empty states then you can have some movement of bonded electrons also
  so if you apply an electric field what happens the electrons will move conduction electrons will move ah opposite to the direction of electric field valence band electrons will also move in that direction but then equivalently we say that the holes have moved in the direction of the electric field
  so in that sense the current which is produced in semiconductor because of this will have two components the component because of the connection electrons and component because of the holes
  so these are the key concepts that i discussed
  so we will take it from here you