INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

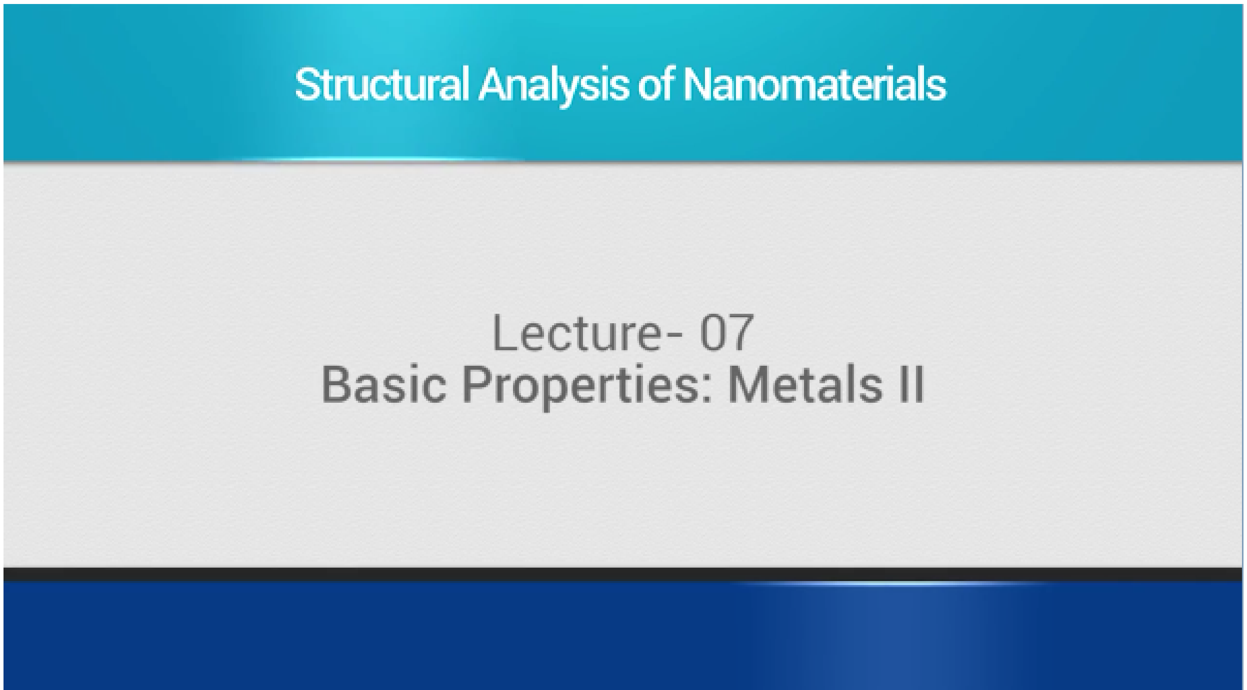
NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Structural Analysis of Nanomaterials

LECTURE – 07
Basic Properties: Metals II

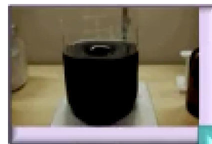
With
Dr. Kaushik Pal
Department of Mechanical & Industrial Engineering
Indian Institute of Technology Roorkee



Hello, in the last chapter or maybe the last discussion we have discussed about the mechanical properties of the metals. In this particular lecture we are going to discuss about the other properties of the metals.

Properties of Metals:

Physical property
- Mechanical property
- Electrical property
- Thermal property
- Magnetic property



Chemical Property
- Reactivity
- Toxicity
- Corrosion

So here actually, already we have discussed about the mechanical properties, so in this particular lecture we are going to discuss about the electrical property, thermal property and the magnetic property of that metals, then chemical property like reactivity, toxicity and the corrosions.

II. Electrical Properties:

General terms for electrical conduction:

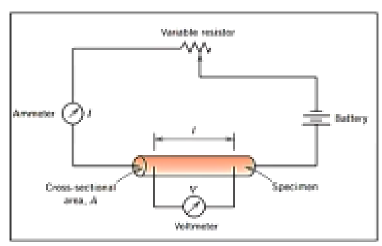
- Ohm's law states that the current (I) through a conductor between two points is directly proportional to the voltage (V) across the two points. Introducing the constant of proportionality, the resistance.

$$V \propto I \Rightarrow V = IR$$

Where, R is the resistance of the material through which the current is passing. The units for V, I, and R are, volts (J/C), amperes (C/s), and ohms (V/A) respectively.

- Electrical resistivity (ρ) is dependent on resistance (R), specimen cross-sectional area (A), and distance (l) between the two points at which the voltage is measured. . The units of ρ is ohm-meter (Ω-m).

$$\rho = \frac{VA}{Il}$$

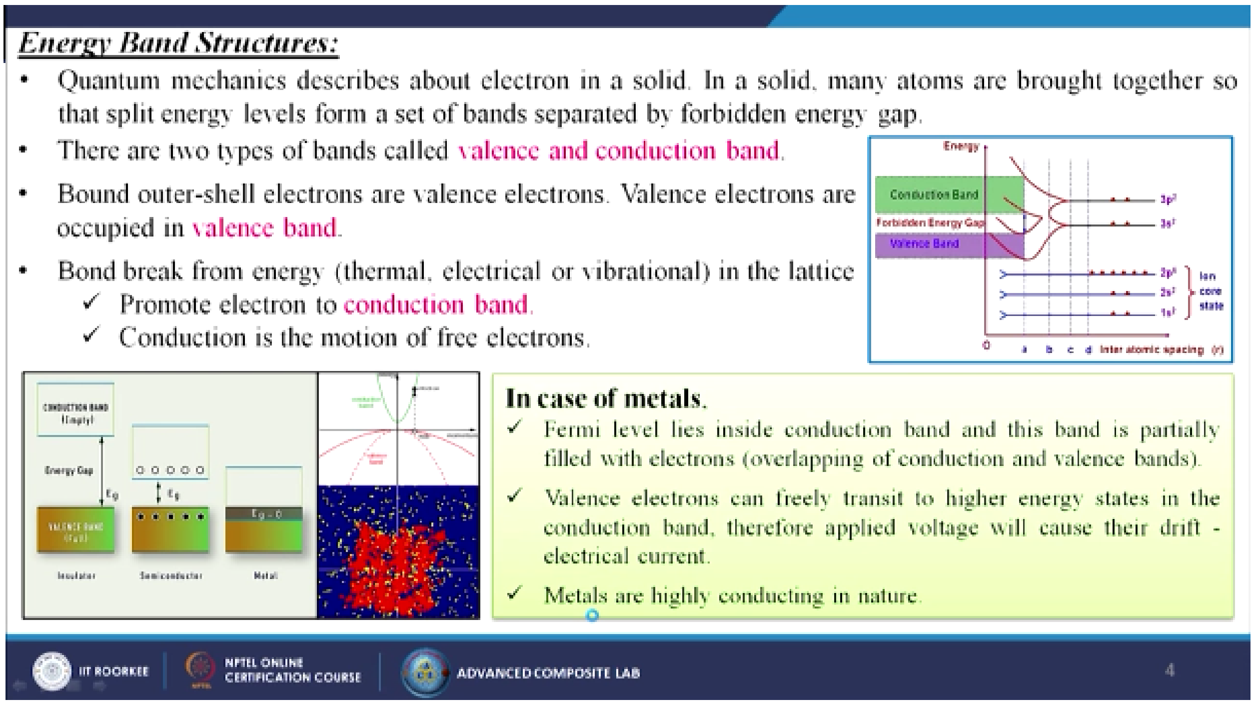


- Electrical conductivity, $\sigma = 1/\rho = Il/VA$

$$\Rightarrow I/A = \sigma V/l = \sigma E = J \text{ (Current density), where E (Electric field)} = V/l$$

So first we will discuss about the electrical properties of the metal itself, so when we are talking about the electrical properties of the metals so first whatever the laws generally we are follow that is known as the ohms law, so what the ohms law states? Ohms law directly states that V is directly proportional to the I, what is V? V is known as the voltage, and I is known as the current passing through, so if we derive that formula properly then we will get that V = IR, here R is the resistance of that particular material, so generally the units of V, I and R are volts, amperes, and the ohms.

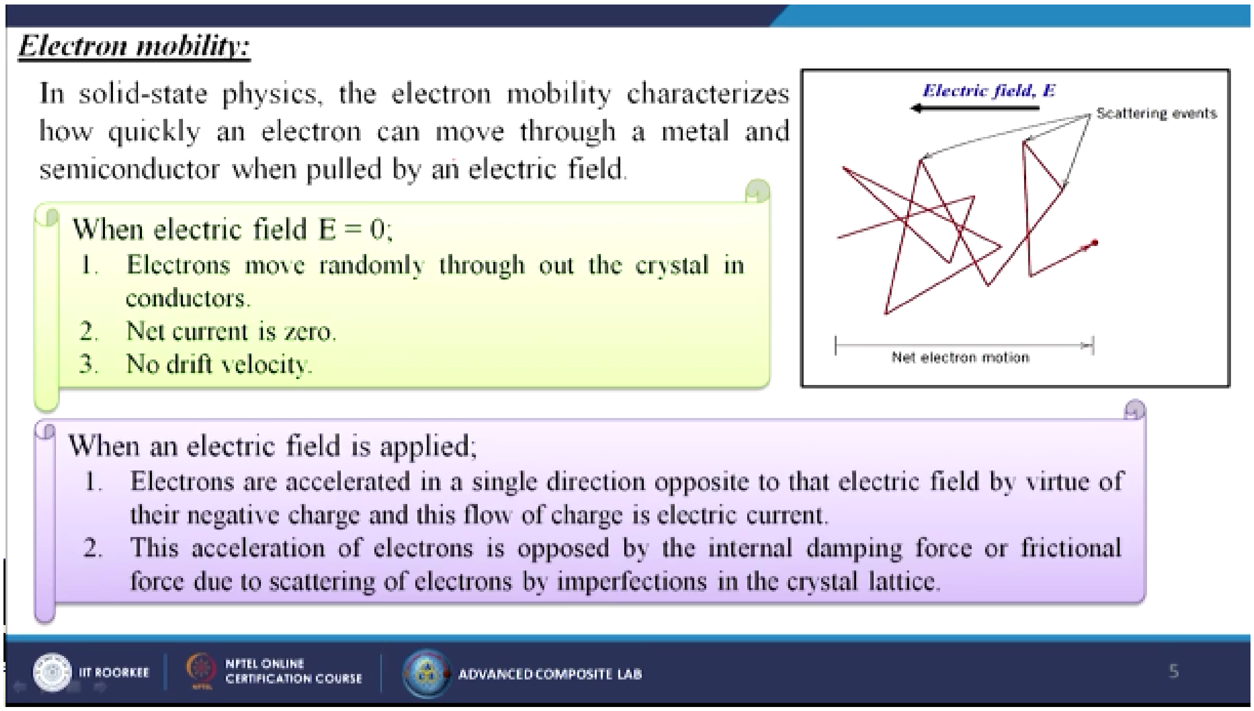
Now when the electricity is passing through any materials, so sometimes its resist also that passing of that electrons, so that is known as the electrical resistivity, so electrical resistivity is depend on the resistance R specimen cross-sectional area, so the cross-sectional area of that particular ware, the total distance travelled so the distance between the two points at which the voltage is measured, so the units of rho is ohmmeter, so generally the rho = VA/IL, so electrical conductivity it is just the opposite of that electrical resistivity, so sigma = 1/rho which is nothing but the IL/VA.



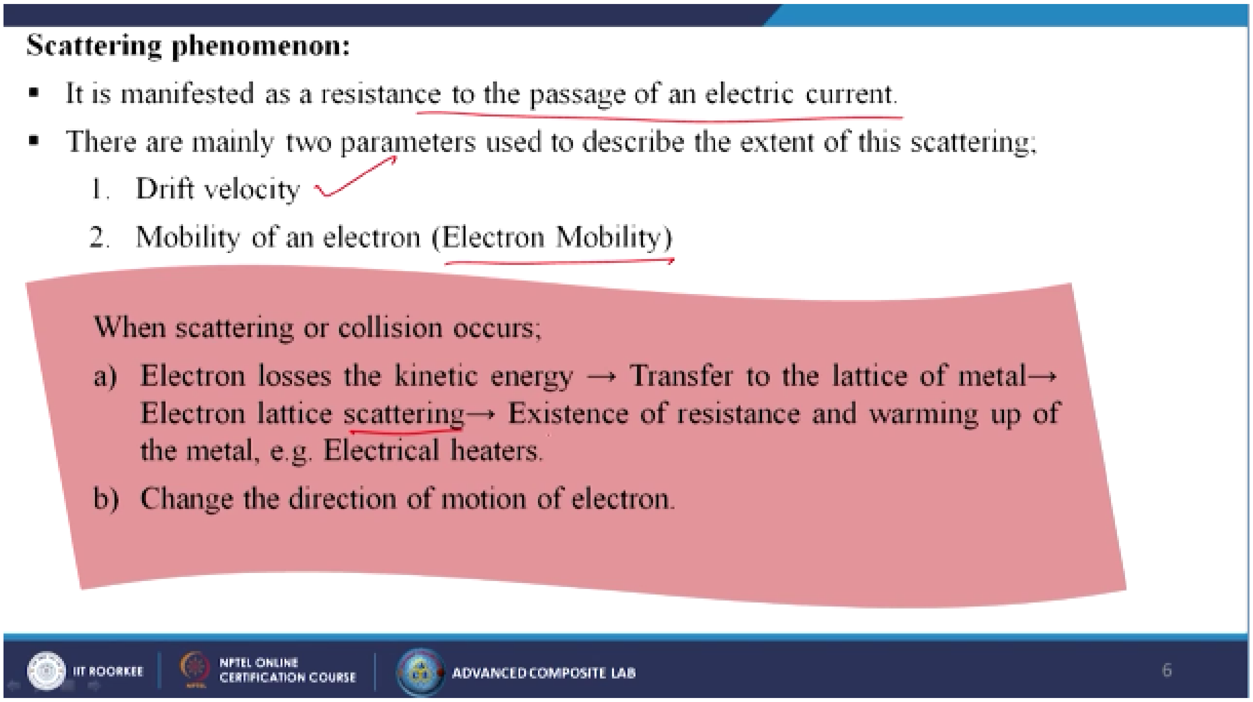
Next we will discuss about the energy band structures of that particular materials, so from the quantum mechanics describes about the electron in a solid, in a solid many atoms are brought together so that the split energy levels from a set of bands separated by the forbidden energy gap, there are two types of bands call the valence band, and another one is known as the conduction band.

Bound outer cell electrons are valence electrons, valence electrons are occupied in the valence band itself, so in this particular case you can find that this all are the valence band, for insulator materials semi-conductor materials and the metals, so bond break from energy like if we give certain energy to that, so the bond may break, what kind of energy it is? Maybe thermal energy, electrical energy or maybe the vibration energy in the lattice which promote the electron to the conduction band that means electron will jump from the valence band to conduction band. Conduction is the motion of free electrons, so when the electron will move then automatically the current flow will start.

So in case of metals Fermi level lies inside the conduction band and this band is partially filled with electrons, overlapping of conduction and the valence band, valence electrons can free transit to higher energy state in the conduction band of course the jumping will be taking place, therefore applied voltage will cause their drift electrical current, metals are highly conducting in nature, so in this particular case you can see that the, how the electron density is changing and also the electron is jumping from the valence band to the conduction band, so when the electron is jumping from valence band to the conduction band, so a hole is created in the valence band itself.



Next we will discuss about the electron mobility, from the name itself you can understand that it is the freeness or maybe the movement of the electron, so in solid state physics the electron mobility characterizes how quickly an electron can move through a metal or semiconductor when pulled by an electrical field, so when electrical field E = 0, electron moves randomly throughout the crystal in the conductors, net current is totally 0, no drift velocity you can find over there, so in this particular case you can find that net electron motion for the scattering events, so it is opposite the electron field, and then when an electron field is applied so in that case electrons are accelerated in a single direction opposite to that electron field by virtue of their negative charge and thus flow of charge in electrical current, of course, because there will be a plus and minus, so automatically if there will be plus then automatically the electron will be attracts to other the current will flow in the opposite directions. This acceleration of electrons is opposed by the internal damping force or frictional force due to scattering of electrons by imperfections in the crystal lattice, nothing in a simple word we have to agitate that electrons to flow from one side to another.



What is the scattering phenomenon? It is manifested as a resistance or to the passage of an electric current, there are mainly two parameters used to describe the extent of this scattering, one is called the drift velocity, another one is called the mobility of an electron which is known as the electron mobility. When scattering or collusions occurs in between the electron, electron loses the kinetic energy, of course they will hit each other, so they will lose the kinetic energy which will transfer to the lattice of that metal, and then electron lattice scattering will be taking place which will help to existence of the resistance and warming up of a metal like electrical heaters, simple when we are using the electrical heaters that means actually in between that the electron are colliding each other due to that their kinetic energy is transformed into the heat energy, or second option is that change the direction of the motions of the electron, so by this two phenomenon we can do the scattering phenomenon or maybe the scattering of the electron.

Drift velocity:

- ✓ The drift velocity (v_d) represents the average electron velocity in the direction of the force imposed by the applied field (E). It is directly proportional to the electric field as follows:

$$v_d \propto E \quad \Rightarrow \quad v_d = \mu_e E$$

Where, the constant of proportionality (μ_e) is called the ***electron mobility***, which is an indication of the frequency of scattering events; its units are square meters per volt-second (m^2/V-s).

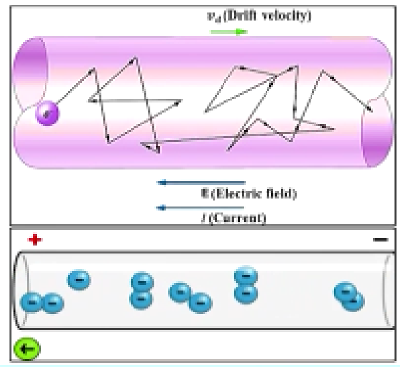
- ✓ The conductivity of most materials may be expressed as

$$\sigma = n\,|e|\,\mu_e$$

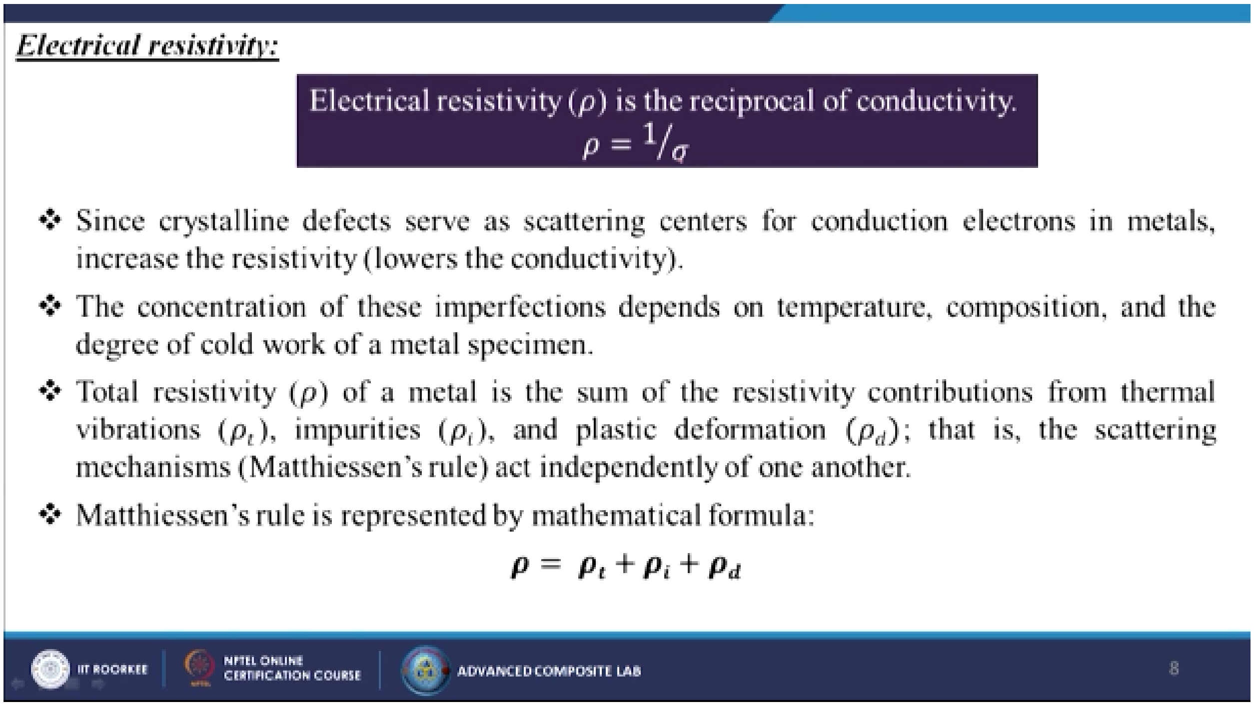
where n is the number of free or conducting electrons per unit volume, and $|e|$ is the absolute magnitude of the electrical charge on an electron (1.6×10^{-19}).

- ✓ $n_{metal} >> n_{semiconductor} >> n_{insulator}$

$\Rightarrow \quad \sigma_{metal} >> \sigma_{semiconductor} >> \sigma_{insulator}$

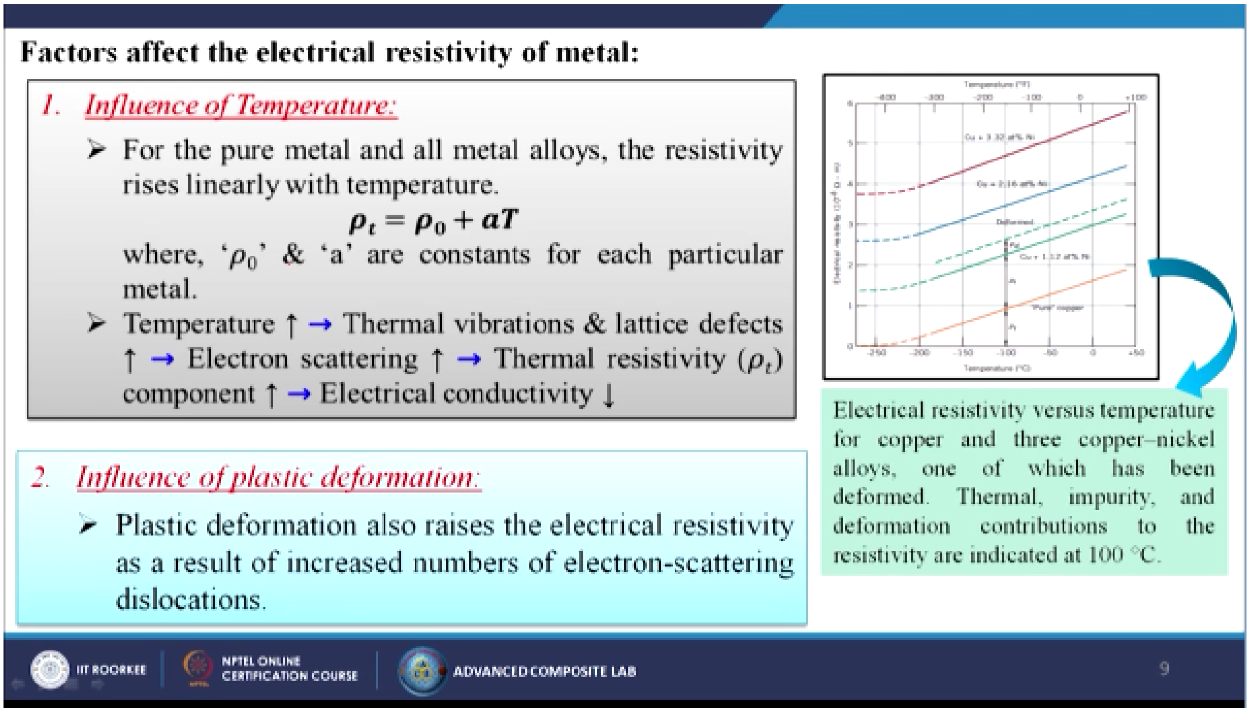


Next is called the drift velocity, so the drift velocity generally VD represents the average electron velocity in the direction of the force imposed by the applied field, it is directly proportional to the electric field as follows, like VD is directly proportional to E, so E is the applied field that means VD = Mu E, mu is nothing but known as the electron mobility, which is an indications of the frequency of scattering events it units are square meters per volt second, the conductivity of most materials maybe expressed at sigma = NE mu E, where N is the number of the free or maybe the conducting electrons per unit volume and E is the absolute magnitude of the electrical charge of an electron that is 1.6 x 10 to the power -19, so N metal is more higher than the N semi-conductor, more higher than the N insulator, so that means the sigma of that metal is more higher than the sigma of the semi-conductor than more higher than the sigma of the insulator, so sigma metal is more greater than the sigma insulator and the sigma semi-conductor, so the conductivity from this particular case we can get the informations about the conductivity, so conductivity of the metal is more higher than the semi-conductor, semi-conductor conductivity is more higher than the insulator, and in the right side bottom image you can get that when there is charge of minus and plus, so when the plus sign is there so automatically all the electrons is going towards in this directions, when the polarity will change then always the electron movement will be in the opposite side, so automatically the kinetic energy will be formed inside the material itself.



Next we will call about the electrical resistivity, it's nothing, it's the opposite of that electrical conductivity, so electrical resistivity is the reciprocal of the electrical conductivity, which is denoted by rho which is nothing but the rho = 1/sigma, so since crystalline defects serve as scattering centers for conduction electrons in metals, increase the resistivity that means it lowers the conductivity.

The concentration of these imperfections depends on temperature, compositions of that particular material and the degree of cold work of a metal specimen. Total resistivity rho of a metal is the sum of the resistivity contributions from thermal vibrations, impurities, and the plastic deformations, that is the scattering mechanism which is known as the Matthiessen's rule act independently of one another, so Matthiessen's rule is represented by this mathematical formula, rho = rho t, that means due to the thermal vibrations then rho I that is due to the impurities, and the plastic deformations that is rho D, so any one of that if it will increase so automatically the rho value or maybe the electrical resistivity of that particular material is going to be increased.



Now we will discuss about the factors which effect the electrical resistivity of the metal itself, so first is called the influence of the temperature, so for the pure metal and all metal alloys the resistivity raises linearly with temperature, so if we increase the temperature of that particular material, so it's electrical resistivity will automatically increase, in this particular equations you can find that rho t = rho 0 + aT, where rho 0 and A are the constants for each particular metal, so from that we can conclude that temperature, if we increase the temperature so thermal vibrations and lattice defects will also increase which in turns increase the electron scattering and then due to that the thermal resistivity component will also increase, then the final result will be automatically the electrical conductivity is going to be decreased.

Next is called the influence of plastic deformations, so plastic deformation also raises the electrical resistivity as a result to increase the number of electron scattering dislocation, so dislocation is taking place inside the materials, from the right hand side figure we can see that electrical resistivity versus temperature of that curve of a copper and 3 copper nickel alloys, one of which has been deformed, thermal impurity and deformation contribution to the resistivity are indicated at 100 degree centigrade, so automatically from this particular case you can see that when we are going to change the constituents of that materials that means we are going to add the more impurity to the origin materials or maybe different materials additions, so their resistivity is going to be changed.

3. *Influence of impurities:*

- For additions of a single impurity that forms a solid solution, Impurity resistivity is related to the impurity concentration (C_i) in terms of atom fraction (at% 100).

$$\rho_i = AC_i(1 - C_i)$$

where, 'A' is a composition-independent constant (impurity and host metals).

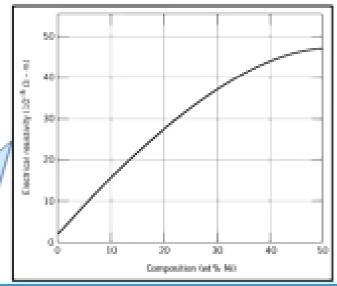
- Two-phase alloy consisting of α and β phases;

$$\rho_i = \rho_\alpha V_\alpha + \rho_\beta V_\beta$$

where, V's & ρ's represent volume fractions and individual resistivities for the respective phases.

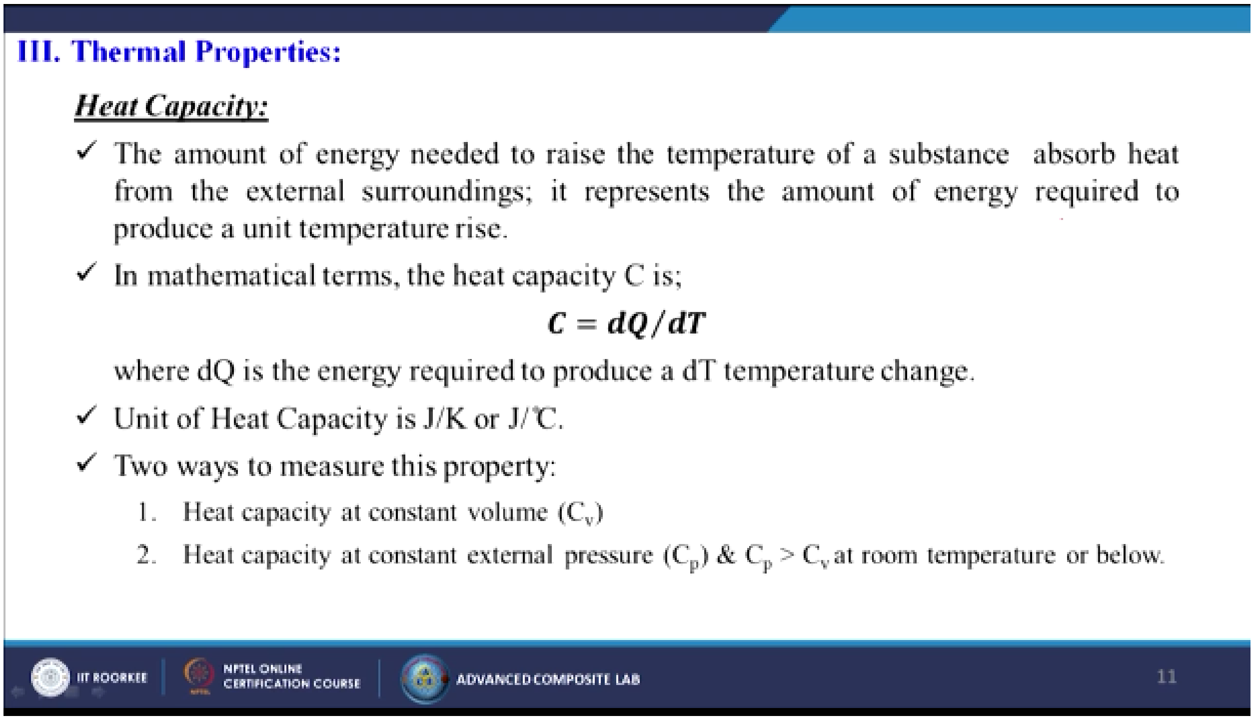
For Example:

- The influence of Ni impurity additions on the room temperature resistivity of Cu is demonstrated up to 50 wt% Ni; over this composition range nickel is completely soluble in copper.
- Ni atoms in Cu act as scattering centers, and increasing the concentration of Ni in Cu results in an enhancement of resistivity.



Next is called the influence of impurities, so for addition of a single impurity that forms a solid solution, impurity resistivity is related to the impurity concentrations, in terms of atom fractions at 100%, so that is denoted by the rho I, which is nothing but the rho I = ACI (1 – CI) where A is the composition independent constant, impurity and host metals.

For two-phase alloy, generally consisting of alpha and beta phases, generally we can see it for the stainless steel or maybe some other kind of materials, so rho I = rho alpha, V alpha and rho beta and V beta, where alpha and beta are the two different phases, so VS and rho is represent the volume fractions and individual resistivity for the respective phases, so for example the influence of nickel impurity, in the right hand side you can see that we are going to increase the nickel percentage from 0 to 50, and how the electrical resistivity is going to be changed, so influence of nickel impurity additions on the room temperature resistivity of copper is demonstrated up to 50 weight percent, so actually this material is made of copper, where we are going to increase the nickel percentage inside that particular matrix, so over this composition range nickel is completely soluble in copper, nickel atoms in copper act as scattering centers, and increasing the concentration of nickel in copper results in an enhancement of the resistivity, so how the resistivity is going to be increased in this particular case.



Next we will discuss about the thermal properties of that metals, so if we discuss about the thermal properties so first the heat capacity comes to our mind, so what is heat capacity? The amount of energy needed to raise the temperature of a substance absorb heat from the external surroundings, it represents the amount of energy required to produce a unit temperature raise, simple from outside we are giving the temperature by which a degree of temperature is going to be increased inside the metal, in mathematical terms the heat capacity is C, generally it is denoted by capital C, so capital C = dQ/dT, where dQ is the energy required to produce at dT temperature change, unit of heat capacity is joule per kelvin or maybe the joule per degree centigrade.

Two ways to measure this properties, because there are two ways by which we can measure the heat capacity of any metals, so first one is known as the heat capacity at constant volume, and heat capacity at constant external pressure, so generally the heat capacity which is at constant external pressure which is nothing but known as the CP is always greater than the CV, that means heat capacity of a constant volume at room temperature or below than that.

Thermal Expansion:

- Thermal expansion is a material property in which a material expands upon heating and contract when cooled, and has units of reciprocal temperature (℃)$^{-1}$.
- The change in length with temperature for a solid material may be expressed as follows:

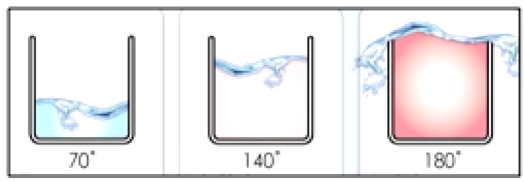
$$\frac{l_f - l_0}{l_0} = \alpha_l (T_f - T_0) \Rightarrow \frac{\Delta l}{l_0} = \alpha_l (\Delta T)$$

where, l_0 and l_f are initial and final lengths with the temperature change from T_0 to T_f respectively. The parameter α_l is called the linear coefficient of thermal expansion.

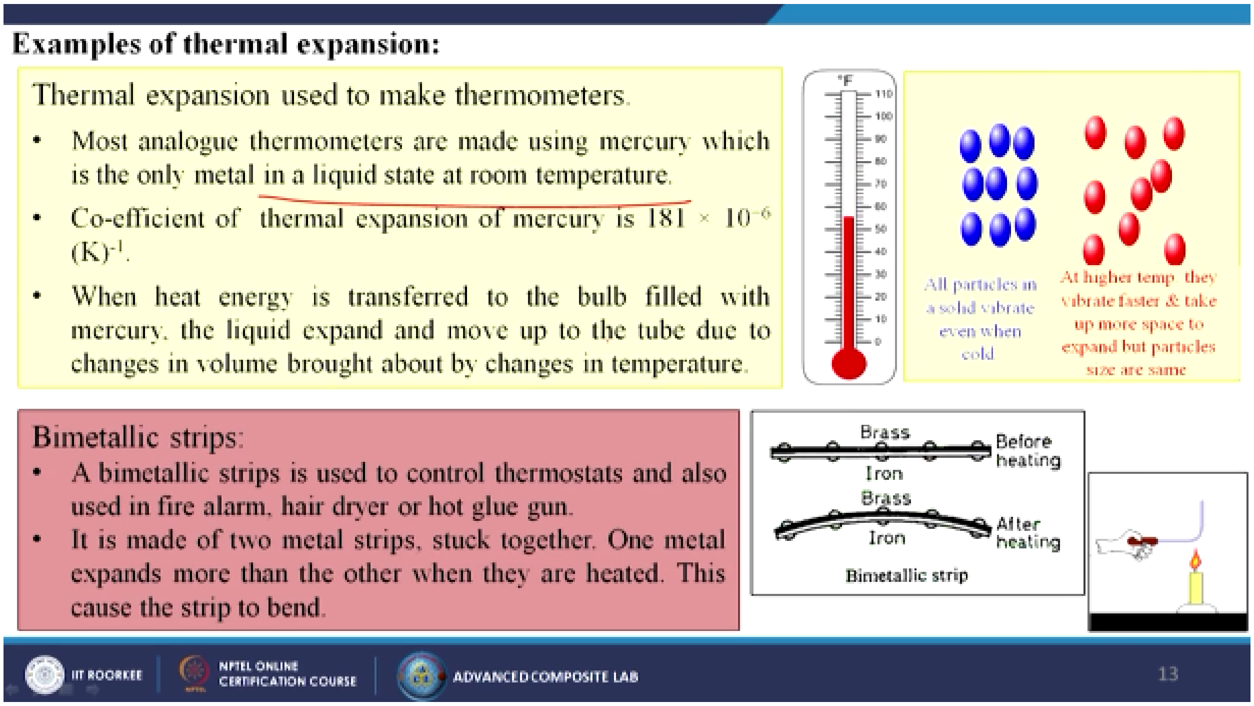
- If a material expands as its temperature raise. This means, the same mass of material occupy a large volume but its density will decrease. Volume change with temperature is;

$$\frac{\Delta V}{V_0} = \alpha_v (\Delta T)$$

where, ΔV and V_0 are change in volume and original volume with the temperature change (ΔT). The parameter α_v is called the volume coefficient of thermal expansion.



Now we are going to discuss about the thermal expansion, so thermal expansion is a material property in which a material expands upon heating and contract when cooled and has units of reciprocal temperature that is 1 by degree centigrade, the change in length with temperature for a solid material maybe expressed as follows, LF-L0/L0, LF is the final length with the temperature change from T0 to TF, and L0 is the initial temperature = alpha L TF – T0, so here the parameter alpha L is called the linear coefficient of thermal expansion, if a material expands as its temperature raise, this means the same mass of material occupy a large volume, but its density will decrease, volume change with temperature is del V/V0 = alpha V into del T, so where del V and V0 are change in volume and original volume with the temperature change del T, the parameter alpha V is called the volume coefficient of thermal expansion, so here from this we can understand that alpha is called the linear coefficient of thermal expansion, and alpha V is known as the volume coefficient of the thermal expansion.



Now example of the thermal expansion, means what is the mechanisms behind it, so most analogue thermometers are made using mercury which is the only metal in a liquid state at room temperature, coefficient of thermal expansion of mercury is 181 x 10 to the power -6 per kelvin, when heat energy is transferred to the bulb filled with mercury, the liquid expands and move up to the tube due to change in volume brought about by change in temperature, so in this case we are going to increase the heat, generally for measuring the fever we are using this kind of thermometer where with our body temperature increases, so automatically the volume expansion of that mercury is taking place by which we can measure the body temperature at that particular time.

So actually what mechanisms, actually when the material is into the room temperature or maybe into the cold conditions, all the particles in the solid vibrates, but at higher temperature they vibrate faster and take up more space to expand but particle size are remain same, so particle size is not going to be change, only the vibrations of that particular particle is going to be increased.

Now we are going to give another best example is called the bimetallic strips, so a bimetallic strips as we know that is a combinations of the brass and iron, so a bimetallic strip is used to control the thermostats and also used in fire alarm, hair dryer or hot glue gun, so what is happening actually, so when it is getting the temperature the thermal expansion of this two different metals like brass and iron are totally different, so in this particular case the brass thermal expansion is more higher than the iron, so that's why it is bending, so it is made of two metal strips stuck together, one metal expands more than the other when they are heated, these cause the strip to bend.

Thermal conductivity:

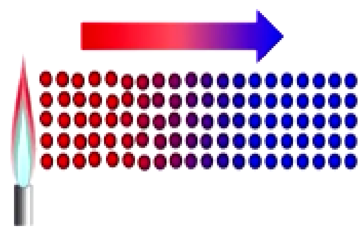
It is the property of a material to conduct heat which is transported from high to low temperature region of a substance. Mathematically;

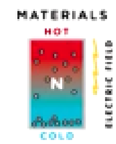
$$q = -k\frac{dT}{dx}$$

Where, q is the heat flux per unit area (W/m^2), k is the thermal conductivity (W/m-K), and dT/dx is the temperature gradient through the conducting medium.

Elements (at 25 °C)	Specific heat (Cal/g °C)	Coefficient of linear expansion (α_l) (× 10^{-6})	Thermal conductivity (k) (watts/cm °C)
Al	0.215	25	2.37
Cr	0.110	6	0.91
Cu	0.092	16.6	3.98
Au	0.031	14.2	3.15
Ni	0.106	13	0.899
Pt	0.032	9	0.73
Si	0.170	3	0.835

Conduction of Heat





Next we will discuss about the thermal conductivity, so it is the property of a material to conduct the heat which is transported from high to low temperature region of a substance, mathematically it is generated by small q, which is nothing but is equal to –K dT/dx, where q is the heat flux per unit area that is watt per meter square, and K is the thermal conductivity watt per meter per kelvin, and dT/dx is the temperature gradient through the conducting medium, so this is the examples of different materials, says like aluminum at 25 degree centigrade, a specific heat is 0.215, coefficient of linear expansion is 25, thermal conductivity means K value is 2.37, when you are talking about the copper its specific heat is 0.092, coefficient of linear expansion is 16.6, and the thermal conductivity is 3.98, when you are talking about the platinum, its specific heat is 0.032, coefficient of linear expansion is 9, thermal conductivity is 0.73, so in this particular case what we are getting that in the cold temperature that material behaves is differently, when we are heating that materials the electric field actually its going into the opposite directions, so when the material is heated up more, so automatically the electrical resistivity of that material is going to be increased.

Mechanism of heat conduction:

Heat is transported in solid materials by both lattice vibration waves (phonons) and free electrons. So, the total conductivity (k) is

k= Lattice vibrational conductivity (k_l) + Electron thermal conductivity (k_e)

- Metals are good conductors of heat because relatively large numbers of free electrons exist that participate in thermal conduction.
- Since free electrons are responsible for both electrical and thermal conduction in pure metals, theoretically suggested that two conductivities should be related according to Wiedemann–Franz law:

$$L = \frac{k}{\sigma T}$$

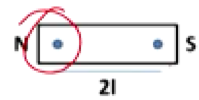
where σ is the electrical conductivity, T is the absolute temperature, and L is a constant. The theoretical value of L is 2.44×10^{-8} Ω-W/K^2, should be independent of temperature and the same for all metals if the heat energy is transported entirely by free electrons.

Mechanisms of the heat conductions, so heat is transported in materials by both lattice vibration waves, which is known as the phonons and free electrons , so the total conductivity K is lattice vibrational conductivity, KL and the electron thermal conductivity which is known as the KE. Metals are good conductors of heat because relatively large number of free electrons exist that participate in thermal conduction, since free electrons are responsible for both electrical and thermal conduction in pure metals, theoretically suggested that two conductivity should be related according to Wiedemann-Franz law which is known as the L = k/sigma T, where sigma is the electrical conductivity, T is the absolute temperature and L is the constant, the theoretical value of L is 2.44 x 10 to the power -8 ohm per watt per kelvin, square, should be independent of temperature and the same for all metals if the heat energy is transported entirely by the free electron itself.

IV. Magnetic Properties:

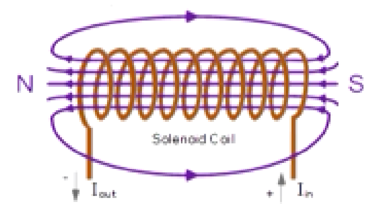
Basic parameters used to study of the magnetic behaviours of materials:

1. **Magnetic moment:**
   Magnetic dipoles are equivalent to electric dipoles, consists of north pole and south pole of strength (m) each separated by a small distance ($2l$).



$$\textbf{Magnetic moment} = m \times 2l$$

2. **Magnetic field strength:** It is generated by means of a cylindrical coil (or solenoid) consisting of N closely spaced turns, having a length l, and carrying a current of magnitude I.

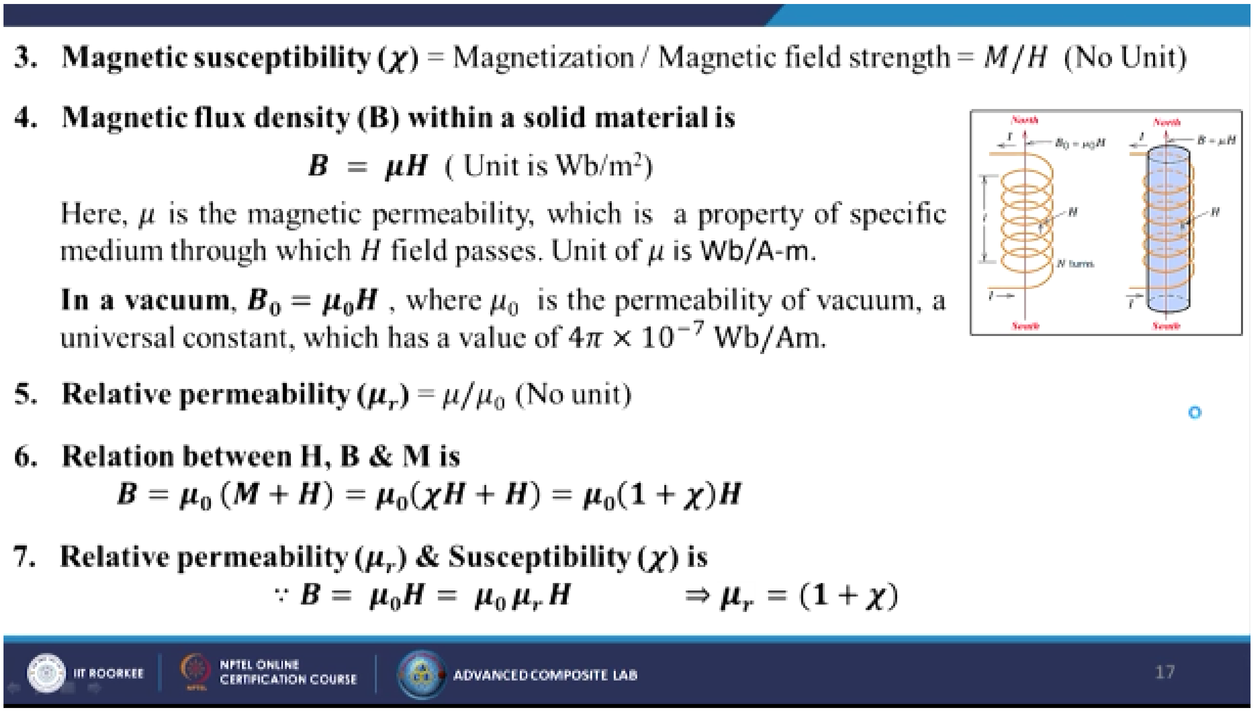


$$H = {nI}/{l}$$

A circular current loop is equivalent to a **magnetic dipole,**

$$\mu_M = I \times A$$

Then we will discuss about the magnetic properties, so magnetic properties generally basic parameters used to study of the magnetic behavior of materials is known as the, first is known as the magnetic moment, so magnetic moment is magnetic dipoles are equivalent to electric dipoles, consist of north pole and south pole and intense in between this two poles is known as suppose it is 2L, so what will be the magnetic moment, the M x 2L, so where M is the strength and if we discuss about the magnetic field strength it is generated by means of a cylindrical coil or maybe the solenoid consisting of N closely spaced turns, having a length L and carrying a current of magnitude I, so H = nI/L, a circular current loop is equivalent to a magnetic dipole, mu M = I x A, so in this particular case we are having that cylindrical coil and then we are giving a current from this side and the current is coming throughout through this side and the magnetic field will be generated inside this solenoid coil.

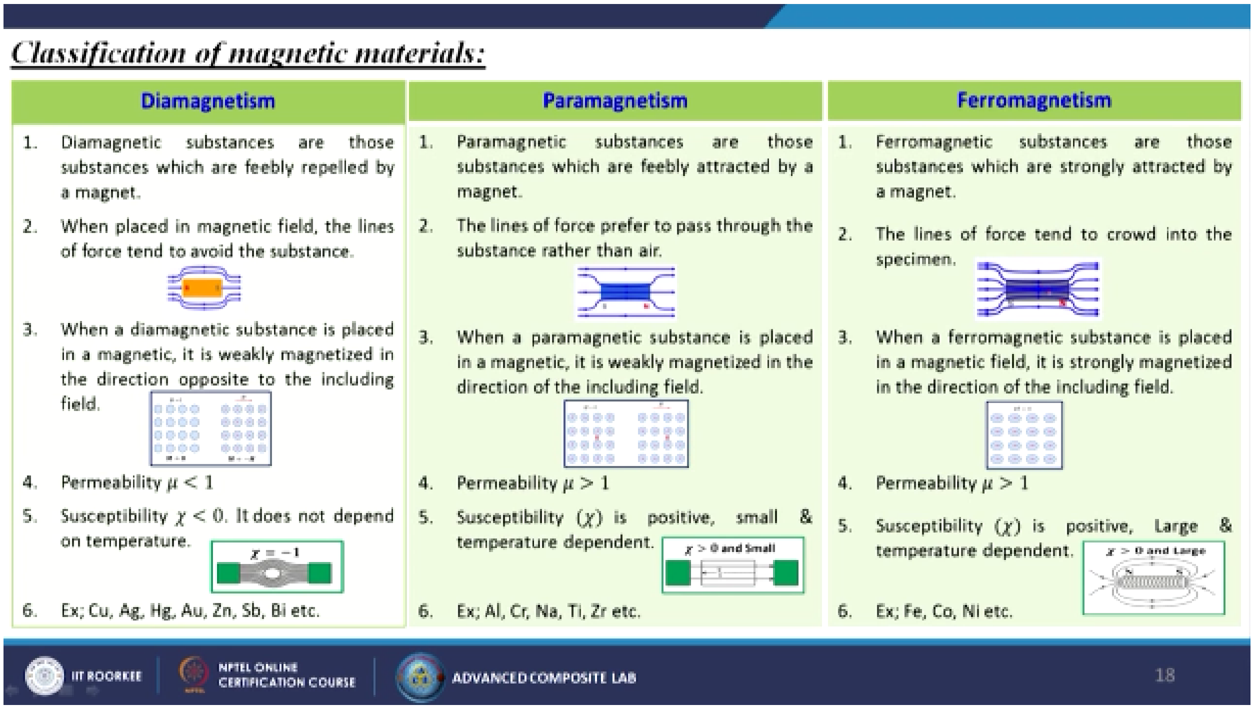


full

Then there are some other properties also, magnetic susceptibility which is known as the chi = magnetizations divided by the magnetic field strength = M/H it doesn't have any unit because both are having the same unit.

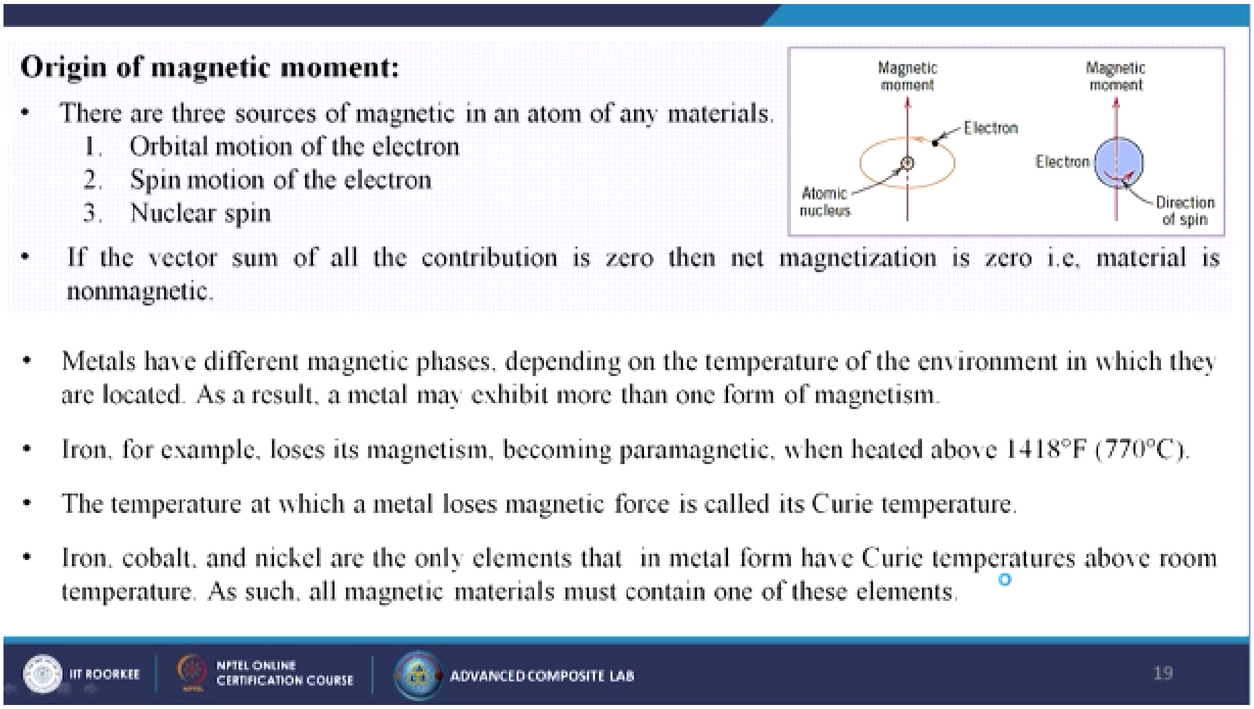
Next we will discuss about the magnetic flux density B within the solid materials, so magnetic flux density is directly proportional to the H, that means field, so here B = mu H which unit is weber per meter square, here the mu is the magnetic permeability which is property of a specific medium through which H field passes, unit of mu is weber per ampere meter. In a vacuum B0 = mu 0H where mu 0 is the permeability of a vacuum, a universal constant which is a value of 4 pi x 10 to the power -7 weber per ampere meter.

Next we will discuss about the relative permeability which is known as the mu R = mu/mu 0, it is also doesn't have any unit, then relations between HB and M is, B = mu 0 x m + H, and relative permeability mu R and susceptibility chi is B = mu 0H = mu 0 x mu RH, or mu R = 1 + chi, which we can get from this particular image, so here you can find that I current is working over there, N is the number of terms, H, here H is known as the field passes through this, and L is the total length of that particular solenoid, so in this particular case by I we know I, we know H, we know B, by which we can calculate the magnetic susceptibility, magnetic flux density, relative permeability, relative, relations between H, B and M and the relative permeability and the relative susceptibility, so from that we can do a very good comparison in between the magnetic materials. So generally the magnetic materials is divided into three parts, one is called the diamagnetism, paramagnetism and the ferromagnetism, diamagnetic substance are those substance which are freely repelled by a magnet, so if we take that material towards the magnet, so it will be repelled by that magnet itself, paramagnetic it will partially allow that material to come closer, ferromagnetic it will fully allow that material to come closer to the magnetic fields.



Second point when placed in magnetic field, the lines of force tend to avoid the substance for the diamagnetism, it will partially allow that materials, the lines of force prefer to pass through the substance rather than air, ferromagnetism the lines of force tend to crowd into the specimen, means it will fully allow that lines. For diamagnetism when a diamagnetic substance is placed in a magnetic, it is weakly magnetized in the direction opposite to the including field, when a paramagnetic substance is placed in a magnetic it is weakly magnetized in the direction of the including field, when a ferromagnetic substance is placed in a magnetic field it is strongly magnetized in the direction of the including field, so permeability mu value for the diamagnetis is less than 1, paramagnetism is greater than 1, and for the ferromagnetism also it is greater than 1.

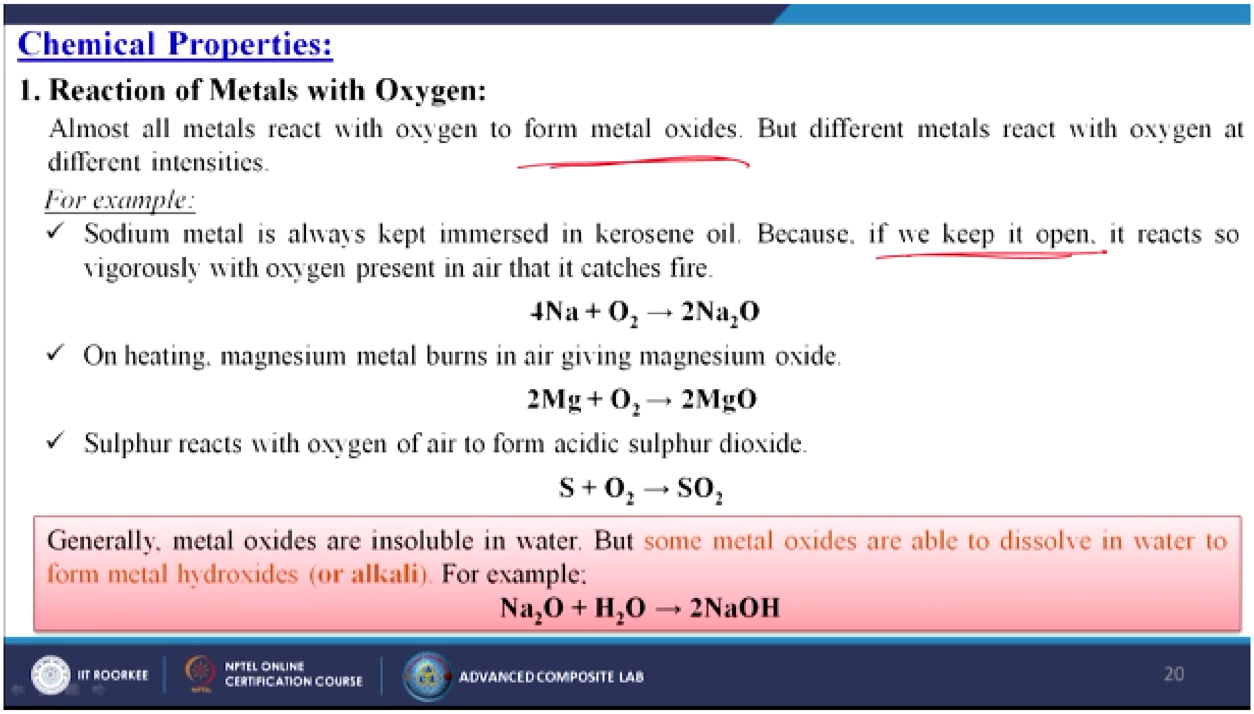
Susceptibility chi value for the diamagnetism it is less than 0, it does not depend on temperature, susceptibility is positive for the paramagnetism, small and temperature dependent, and for ferromagnetism it is positive, large and totally temperature dependent. Example of the diamagnetism materials are copper, silver, mercury, gold, zinc, antimony and bismuth. For paramagnetism it is aluminum, chromium, sodium, titanium, zirconium. And ferromagnetism it



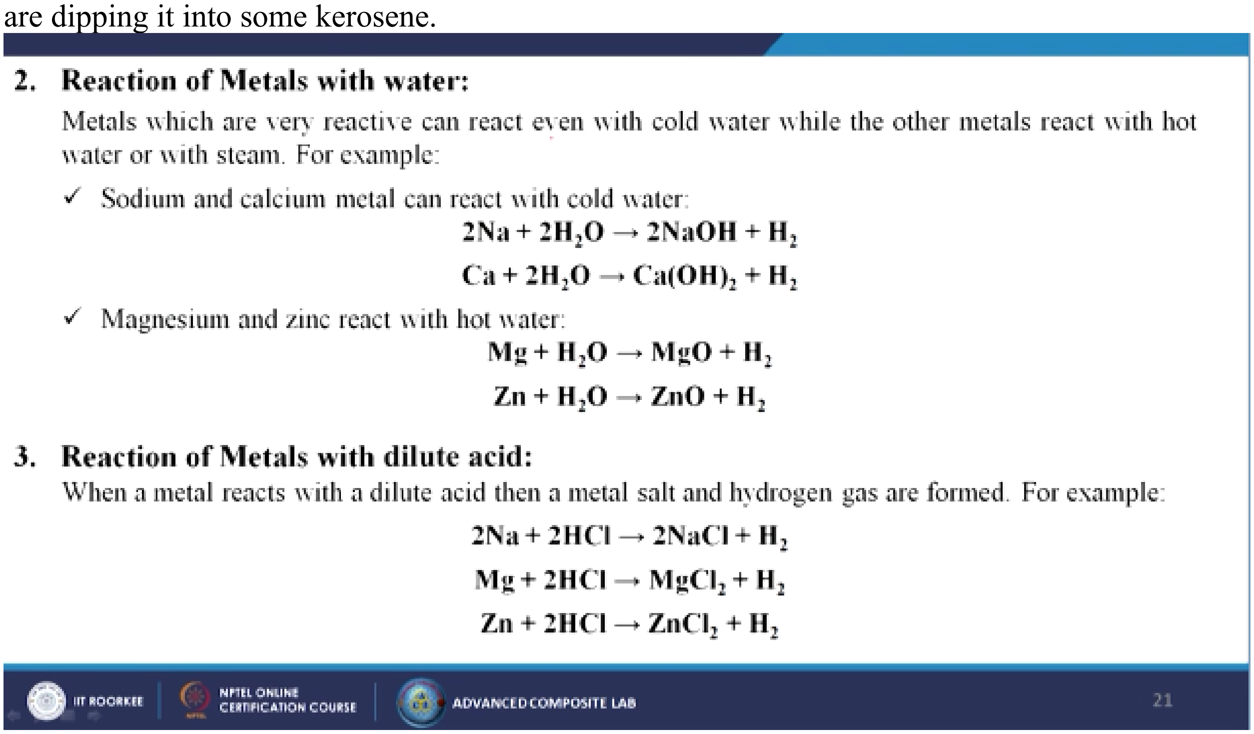
is iron, cobalt, nickel etcetera, so what is the origin of that magnetic moment, so there are three sources of magnetic moment in an atom of any material, first one is called the orbital motions of the electron, second is called the spin motion of the electron, and third one is called the nuclear spin.

So if the vector sum of all the contributions is 0, then net magnetization is 0, material is nonmagnetic material, metals have different magnetic phases depending on the temperature of the environment in which they are located, as a result a metal may exhibit more than one form of magnetism at a time, iron for example loses its magnetism becoming paramagnetic when heated above 1418 degree Fahrenheit or maybe 770 degree centigrade.

The temperature at which a metal loses magnetic force is called the curie temperature, iron, cobalt and nickel are the only elements that in metal form have curie temperatures above room temperature as such all magnetic material must contain one of this elements, like iron or maybe cobalt or maybe the nickel, so here just this image you simply giving us the informations about the orbital motions, the spin motions of the electrons and the nuclear spin.

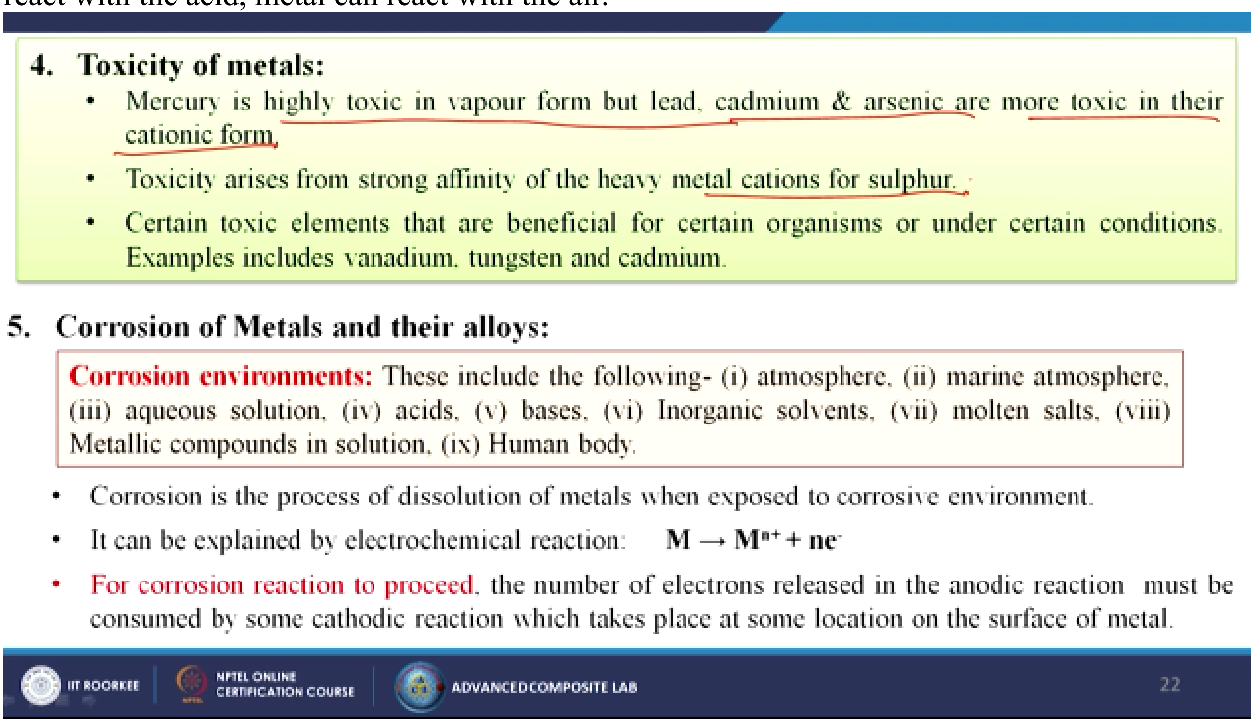


Next we will discuss about the chemical properties of metals, so reaction of metals with the oxygen, which is the normal phenomena generally we can find while using some metals, so almost all metals react with oxygen to form the metal oxides, but different metals react with oxygen at different intensities, for example sodium metal is always kept immersed in kerosene oil, because if we keep it open it reacts to vigorously with oxygen present in air, and it will catch the fire, so that's why we are putting or maybe while keeping the sodium in the lab, generally we are dipping it into some kerosene.



On heating magnesium metal burns in air giving the magnesium oxide MGO, sulphur reacts with oxygen of air to form the acidic sulphur dioxide, so generally metal oxides are in soluble in water, but some metal oxides are able to dissolve in water to form metal hydroxides or alkali, for example the sodium hydroxide which is known as the NAOH, then reaction of the metals with water, metals which are very reactive can react even with cold water while the other metals react with hot water or with steam, so it actually depends upon the chemical properties of that particular metals. Sodium and calcium metal can react with cold water, and it can form the calcium hydroxide and sodium hydroxide, magnesium and zinc react with the hot water which can form the magnesium oxide and the zinc oxide, and they will evolve the hydrogen gases from that particular reaction.

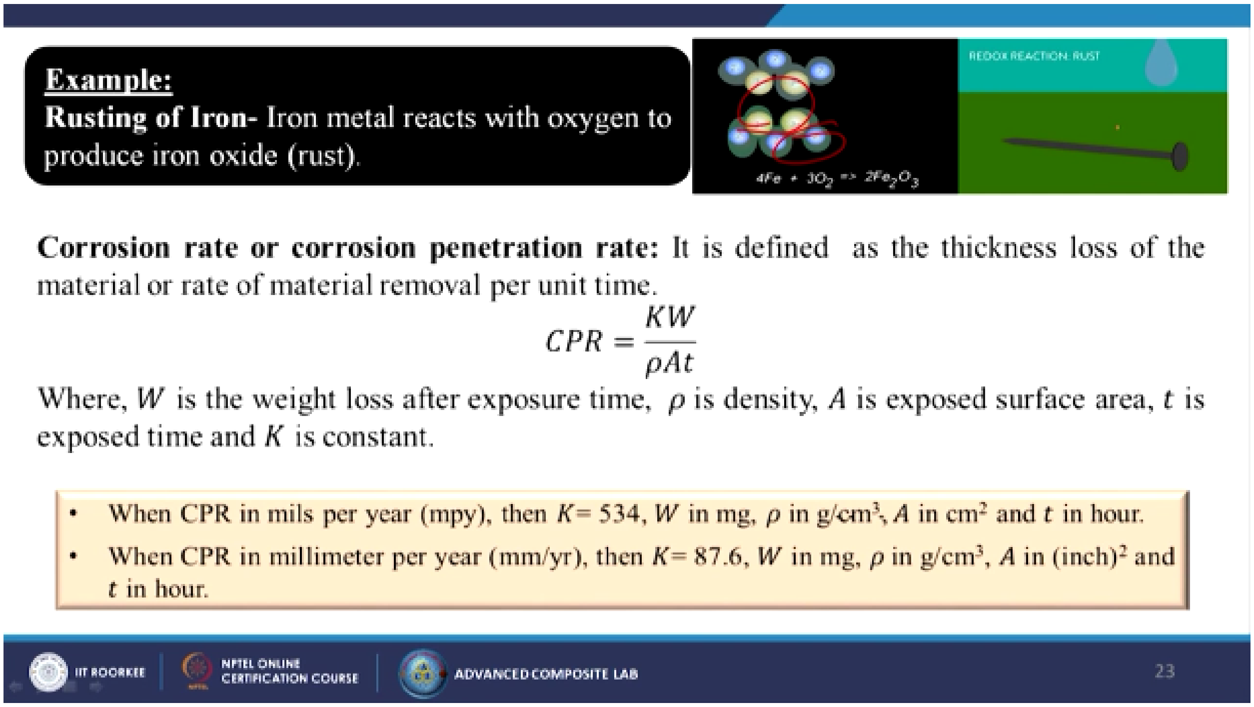
When a metal reacts with a dilute acid then a metal salt and hydrogen gas are formed, for example 2NA + 2HCL it can form the sodium chloride and the hydrogen gas. Magnesium and hydro chloric acid form the magnesium chloride + hydrogen gas. Zinc and hydrochloric acid forms the zinc chloride and the hydrogen gas, so the metal can react with the water, metal can react with the acid, metal can react with the air.



Next we will discuss about the toxicity of the metals, yes of course we are using, nowadays we are using that metals for the biomedical applications also, but there are some metals like magnesium which the toxicity is very, very less, but there are some other metals which is very highly toxic in nature, so mercury is highly toxic in vapour form, but lead, cadmium, arsenic are more toxic in their cationic form.

Toxicity arises from strong affinity of the heavy metals, cations for sulphur. Certain toxic elements that are beneficial for certain organisms or under certain conditions, example includes vanadium, tungsten, cadmium, so these all some sorts of helpful toxic materials.

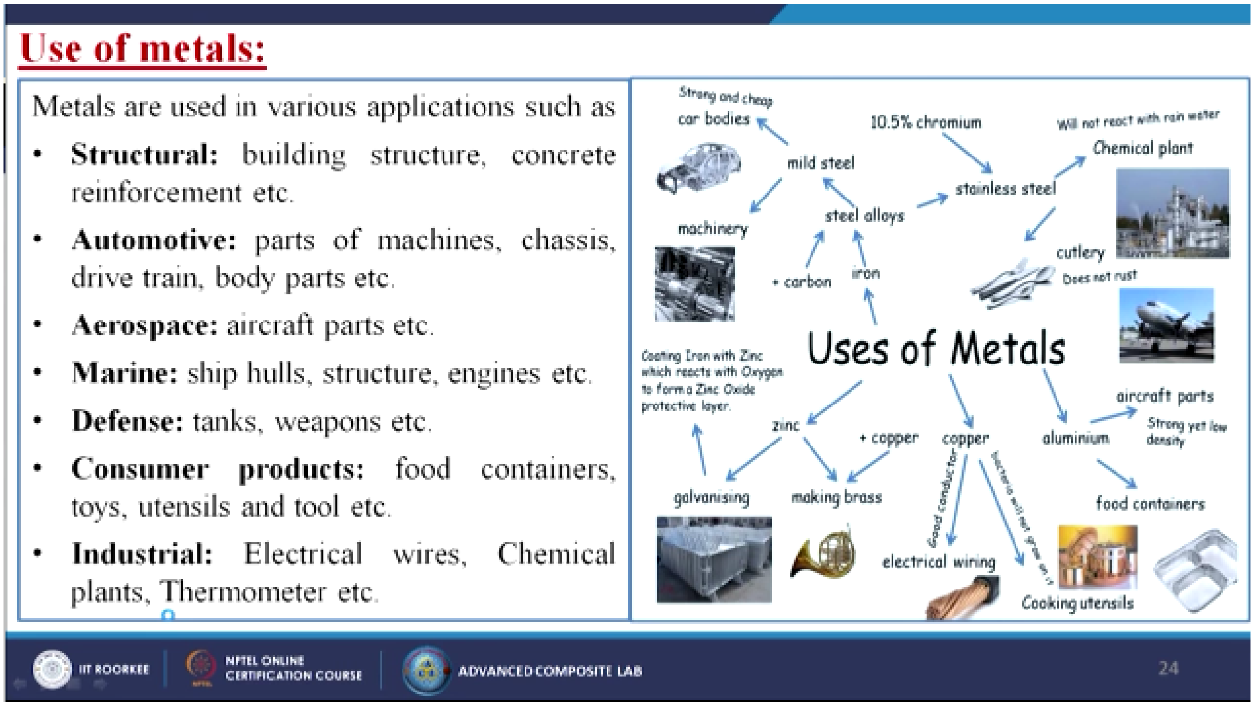
Corrosion of metals and their alloys, corrosion environments this includes the following atmosphere, marine atmosphere, aqueous solution, acids, bases, inorganic solvents, molten salts, metallic compounds in solutions and the human body. Corrosion is the process of dissolutions of metals when exposed to corrosive environment of course, you have to take out that material into the corrosive environment, it can be explained by the electrochemical reactions that + ion and the electron will be generated, for corrosion reactions to proceed the number of electrons released in the anodic reaction must be consumed by some cathodic reaction which takes place at some location on the surface of metal.



Example, rusting of iron, iron metal reacts with oxygen to produce the iron oxide or maybe the rusting, so here you can find out the iron and when it is coming into the contact with the oxygen it is formed the Fe2O3 which is here, so redox reaction is taking place so the actually the iron and the oxygen, the interatomic bonding is taking place over there, so due to that the rusting formation is taking place.

Corrosion rate or corrosion penetration rate it is defined as the thickness laws of the material or rate of material removal per unit time, so generally it is denoted by the CPR, corrosion penetration rate = KW/rhoAT, where W is the weight loss after exposure time, rho is the density, A is exposed surface area, T is the exposed time and capital K is the constant.

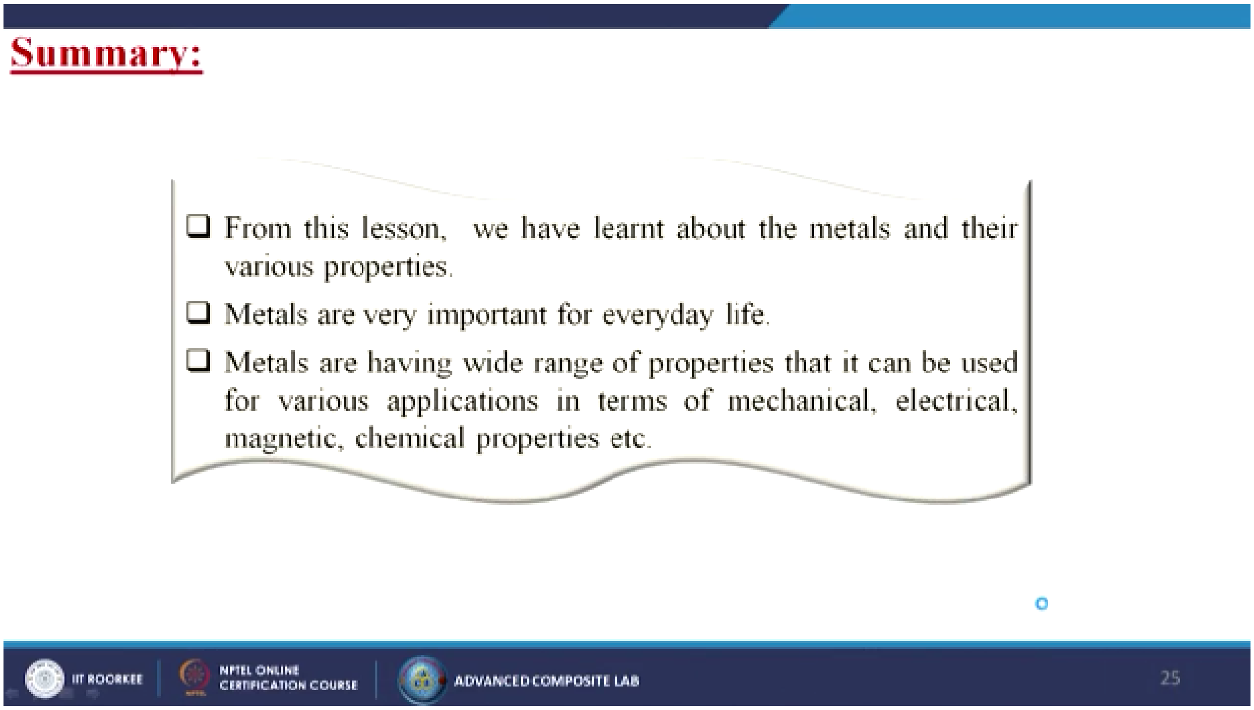
Where CPR in mils per year, generally the K value at the time is 534, W in MG, rho in gram per centimeter cube, area in centimeter square, and the time is in hour, where CPR in millimeter per year, then K = 87.6, W in MG, rho in gram per centimeter cube, A in inch per inch square, and T is in hour.



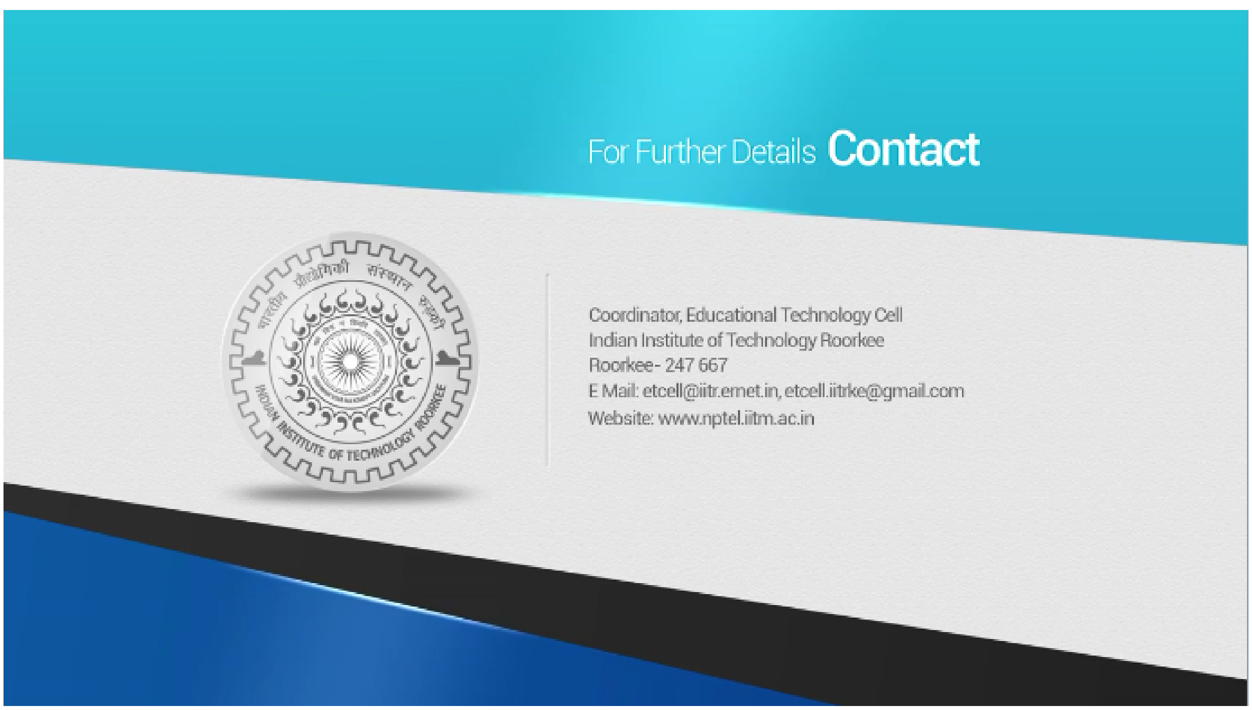
Now we will discuss about the use of all this metals, so metals as I told at the starting of this particular lecture that we are using it for the various, various applications, numerous applications, such as structural for making the building, architecture, concrete reinforcement etcetera.

Automotive, parts of machines, chassis, drive train, body parts etcetera. For aerospace generally aircraft applications, we are using the aluminum alloy.

Marine, for ship hulls, structure, engines etcetera we are making. Defense for tanks and weapons we are using. Consumer products, food containers, toys, utensils and tool etcetera. Industrial electrical wires, chemical plants and thermometers, but in a simple term if I can say that this is a very small applications, there are n number or maybe plenty of applications where we are using this metals, so generally from the right hand side image you can find that whatever I have already discussed we are using for several purposes in the chemical plant, aircraft parts, cooking utensils, galvanizing, machinery, car bodies, electrical wiring, making brasses or maybe any kind of alloys and everything.



So now we are going to summarize this materials, so from this particular lessons we have learnt about the metals and their various properties, metals are very important for everyday life, and metals are having a very wide range of applications, or maybe the properties like thermal properties, electrical properties, magnetic properties or some chemical properties due to that we are going to use this metals for very, very large applications. Thank you.



For Further Details Contact

Coordinator Educational Technology Cell
Indian Institute of Technology Roorkee
Roorkee-247 667
E Mail:- etcell@iitr.ernet.in, etcell@iitrke@gmail.com
Website:- www.nptel.iitm.ac.in

Acknowledgement
Prof. Ajit Kumar Chaturvedi
Director, IIT Roorkee

NPTEL Coordinator
Prof. B.K Gandhi

Subject Expert
Dr. Kaushik Pal
Department of Mechanical and Industrial Engineering
IIT Roorkee

Produced By
Mohan Raj. S

Graphics
Binoy. V.P

Web Team
Dr. Nibedita Bisoyi
Neetesh Kumar
Jitender Kumar
Vivek Kumar
Dharamveer Singh
Gaurav Kumar

An Educational Technology Cell
IIT Roorkee Production