CHAPTER # 17

PHYSICS OF SOLIDS

INTRODUCTION

The use of materials for specific purposes depends upon their properties or features like hardness, ductility and malleability (conversion of materials in to sheets and wires), conducting or magnetic. The question arises what makes the

Steel hard

Lead soft

Iron magnetic and

Copper electrically conducting.

All the above mentioned features depend upon the structure, definite order and bonding of atoms in material.

SOLIDS

 # Definition # Those substances which are rigid, hard and have a definite shape and volume due to closely packed atoms, ions and molecules held together by strong cohesive forces are called solids.

On the basis of internal structure, arrangement of constituent particles and intermolecular bonding forces, solids can be grouped in to following main branches.

http://www.phycity.com

(i) CRYSTALLINE SOLIDS :-

(ii) AMORPHOUS SOLIDS :-

(iii) POLYMERIC SOLIDS :-

(i) # CRYSTALLINE SOLIDS

Def:- Those solids in which atoms, ions or molecules are arranged in a regular and repeating pattern that can extends in three dimensions are called crystalline solids.

-: Examples:- Copper, Iron, Zinc, Sodium chloride Zirconia etc.

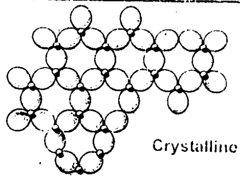
-: Features:- Following are the main features of crystalline solids

(i) Atoms, ions or molecules are not perfectly Static.

(ii) The amplitude of vibration of constituent particles about their mean position increases with the rise in temperature.

(iii) A strict longrange order b/w the molecules, atoms, or ions exists due to strong Cohesive forces

(iv) Every crystalline solid has a definite melting point i.e. it melts completly in 2°



Crystalline

http://www.phycity.com

N.B. # MELTING POINT

Def:- The temperature at which the amplitude of vibration of particles about their lattice sites becomes so large that the structure suddenly breaks inside solids is called its melting point.

(ii) # AMORPHOUS SOLIDS

Def:- The word amorphous means without form or structure

" Those solids whose constituent atoms, ions or molecules donot possess a regular orderly arrangement are called amorphous solids.

Examples:- Glass, plastics, Glue etc.

Features:-

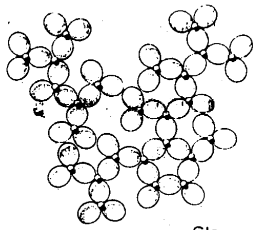
(i) They are more like liquids with disordered structure frozen in

(ii) A long range regularity does not exist

(iii) They have no definite melting point

(iv) They gradually soften in to paste like materials and become viscous at a certain high temperature like glass which after melting becomes viscous liquid nearly at 800 $^\circ C$. That is why these solids are called

http://www.phycity.com



Glassy

Glassy and crystalline solids-short- and long-range order.

POLYMERIC SOLIDS

Def:- Those solids which are said to be more or less solid materials with a structure that is intermediate b/w order and disorder are called polymeric solids or polymers

:Examples:- polythene, polystrene, Nylon etc

Features:-

(i) They are massive long chain synthetic materials formed by the combination of relatively simple molecules in polymerization reactions

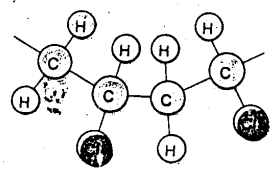
(ii) They have rather low specific gravity compared with even the lightest of metals

(iii) They have good strength-to-weight ratio.

(iv) They are the combination of carbon with hydrogen, nitrogen, oxygen, metallic or non metallic elements. e.g. Natural rubber in its pure form is entirely composed of hydrocarbon with the formula $(C_5H_6)_n$

http://www.phycity.com

Visit us at
http://WWW.PHYCITY.COM



Part of a PVC molecule

UNIT CELL

Def:- The smallest basic three dimensional structure of any substance having definite angles, corners and edges is called unit cell.

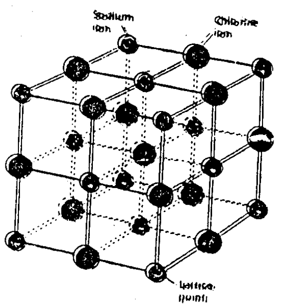
CRYSTAL LATTICE

Def:- The whole structure which is obtained by the repitition unit cell is called crystal lattice or space lattice.

Due to the variation of cell dimensions or cell parameters in different materials, crystal lattice can be classified in to following main branches.

(i) Cubic (ii) Tatragonal (iii) Orthorhombic
(iv) Monoclinic (v) Hexagonal (vi) Triclinic
(vii) Rhombohedral or trigonal.

The structure of NaCl is cubic in which all the sides meet at right angles as shown below.



http://www.phycity.com

MECHANICAL PROPERTIES OF SOLIDS

DEFORMATION :-

Def:- Any change in shape, volume and length of an object when it is subjected to some external force is called deformation.

DEFORMATION IN SOLIDS

In order to explain the concept of deformation, let we see the following examples.

If we hold a soft rubber ball in our hand and then squeeze it by applying force, it causes a change in its shape or volume. If now we stop squeezing the ball by opening our hand it will return to its original shape as shown in the fig.

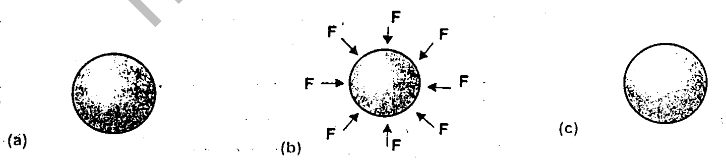


Fig 17.1
(a) Original rubber ball
(b) Squeezed rubber ball subjected force F by the hand
(c) Rubber ball after removing force

Similarly if we hold a rubber string in our hand and apply a certain force by moving our hand apart. The length of the string will increase. The extension produced in the string is proportional to the applied force provided

http://www.phycity.com

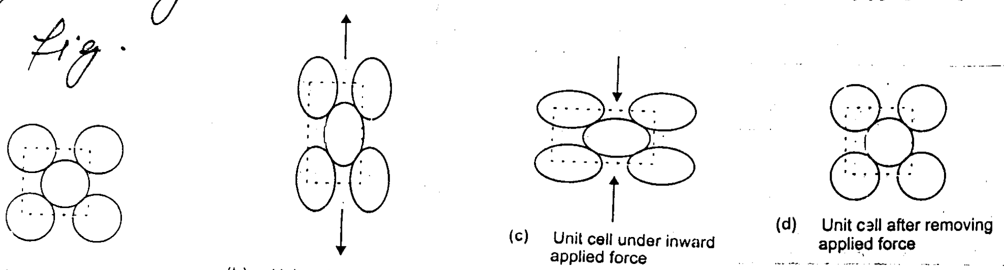
~~that elastic limit is not reached~~

DEFORMATION IN CRYSTALLINE SOLIDS

In case of crystalline solids, the atoms are tightly held about their equilibrium position in a definite order. The strength of these solids is dependant on the interatomic cohesive forces. On applying external force, the atoms in crystalline solids are displaced from their mean position and thus create a deformation. At this instant the material is in the state of stress. If now the applied force is removed, the atoms inside the material regain their equilibrium position. This will happen only the applied force was within its elastic limit.

ELASTICITY

Def:- The ability of a body to return to its original shape is called elasticity. The deformation produced in the unit cell of a crystalline material is shown in the fig.



(a) Unstretched unit cell (b) Unit cell under outward stretching force (c) Unit cell under inward applied force (d) Unit cell after removing applied force

http://www.phycity.com

STRESS

Def:- The force applied on a unit area of an object produce a change in its shape, length or volume is called stress. It is denoted by σ (sigma) and is mathematically expressed as.

$$\sigma = \frac{F}{A}$$

The S.I unit for stress is Nm^{-2} or pascal.

TYPES OF STRESS

(i) # TENSILE STRESS

Def:- A stress that causes a change in length of an object is called tensile stress.

(ii) # COMPRESSIONAL STRESS

Def:- A stress applied to an object that results a change in its volume is called compressional stress.

(iii) # SHEAR STRESS

Def:- A stress that may cause a change in the shape of an object is called shear stress.

STRAIN

Def:- It is the measure of deformation in a solid under the influence of some external force. It is defined as.

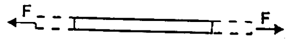
" The ratio of change in length to the original length OR the fractional change in length "

http://www.phycity.com

Being a ratio of two identical quantities it is a dimensionless quantity:-
Such a strain is also called linear strain.

TENSILE STRAIN

Def: A strain that occurs due to tensile stress (σ) is called tensile strain



(a)

COMPRESSIONAL STRAIN

Def A strain produced in an object as a result of compressive stress is called compressive strain.

VOLUMETRIC STRAIN

Def:- The change in volume per unit original volume under the influence of an applied stress is called volumetric strain.

OR

The fractional change in volume is known as volumetric strain.

If ΔV be the change in volume of an object having an original volume V_o the

$$\text{Volumetric Strain} = \frac{\Delta V}{V_o}$$

It is also a dimensionless quantity:-

SHEAR STRAIN

A strain produced in the opposite faces of a rigid cube when it is subjected to shear stress is called shear strain
It is denoted by γ and is given as.

http://www.phycity.com

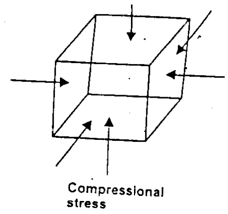
$$\gamma = \frac{\Delta a}{a} = \tan\theta$$

If θ is very small then

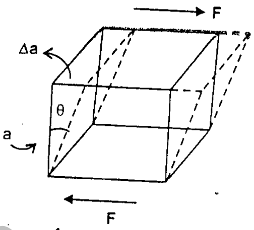
$\tan\theta \simeq \theta$ (radian)

So $\gamma = \theta$

(b)



(c)



MODULUS OF ELASTICITY

Def:- The ratio of stress to the strain for a given material is always constant provided that the applied force is not too great. Such constant is referred as modulus of elasticity. Hence

$$\text{Modulus of Elasticity} = \frac{\text{Stress}}{\text{Strain}} = \frac{\sigma}{\epsilon}$$

Its unit is same as that of stress i.e. pascal or Nm^{-2}

YOUNG'S MODULUS

#Def# The ratio of tensile stress σ to tensile strain is called Young's Modulus.

Mathematically it is expressed as

$$Y = \frac{\sigma}{\epsilon} = \frac{F}{A} \div \frac{\Delta l}{l}$$

$$Y = \frac{F \times l}{A \times \Delta l}$$

BULK MODULUS

#Def# The ratio of applied stress to volumetric strain is called Bulk Modulus. It is denoted by K

http://www.phycity.com

Mathematically

$$K = \frac{F/A}{\Delta V/V} = \frac{FV}{A\,\Delta V}$$

SHEAR MODULUS

 # Def # The ratio of shear stress to shear strain is called shear modulus. It is denoted by G and is given as

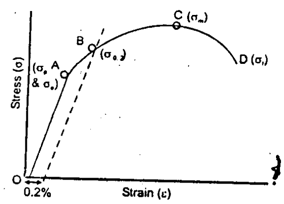
$$G = \frac{\tau}{\gamma} = F/A \div \tan\alpha$$

$$G = \frac{F}{A \tan\alpha}$$

ELASTIC LIMIT AND YIELD STRENGTH

In tensile test, the deformation produced in a metallic wire along with its respective stresses are continuously measured by an electronic device fitted inside a mechanical testing machine. A stress strain curve for a ductile material plotted on X-Y chart recorder is shown in the fig.

At initial stage of deformation the stress increases linearly with the strain till a point on the curve called Proportional Limit (σ_p)



PROPORTIONAL LIMIT

Def # The greatest stress that a material can face without losing straight line proportionality b/w stress and strain is called proportional limit.

http://www.phycity.com

It is denoted by σ_p

proportional Limit σ_p Can also be referred as elastic Limit σ_e

ELASTIC LIMIT

Def # greatest stress endured (faced) by a material without any permanent change in its shape or dimensions is called elastic Limit.

It is obvious from the curve that **Hook's Law** is valid in the region OA i.e. "Stress is directly proportional to strain provided that the elastic Limit is not reached."

The deformation produced in region OA is not permanent but is temporary called elastic deformation.

ELASTIC DEFORMATION

Def # The deformation produced inside a material which has an ability to regain its original shape or dimension after removing the applied stress is called elastic deformation.

From point A onwards, if now stress is increased beyond elastic limit, a permanent deformation occurs and the material will never recover its original shape or volume and exhibits plastic behaviour.

The point C on the Curve represents Ultimate Tensile Strength (UTS) σ_m

http://www.phycity.com

ULTIMATE TENSILE STRENGTH

Def # The maximum stress that a material can withstand is called ultimate tensile strength.

After crossing the point C, the material gets fractured at point D showing fractured stress (σ_f)

DUCTILE SUBSTANCES

Def # The substances which undergo plastic deformation are called ductile substances e.g. Lead, Copper, iron etc

BRITTLE SUBSTANCES

Def # The substances which break just after the elastic limit is reached are called brittle substances e.g. glass, High Carbon steel.

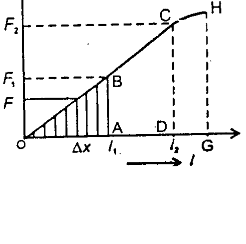
STRAIN ENERGY IN DEFORMED MATERIALS

STRAIN ENERGY

Def # The amount of P.E. stored in a material due to displacing of its molecule from their mean position is called strain energy.

DERIVATION

Let a wire whose one end is attached to a fixed support is stretched vertically by connecting a weight at its lower end which acts as a stretching force. The extension l of the wire can be increased by increasing the stretching force F. The graph plotted b/w extension l for different values of stretching force F is shown in the fig.



http://www.phycity.com

It is evident from the curve that within elastic limit, force F is proportional to extension l. while stretching wire, some work is to be done by the force F which is equal to the product force F and extension l. In order to calculate the workdone for extension l_1 by a certain force F_1, it is clear that force is not constant but is changing linearly from 0 to F_1 through extension l_1. Hence it is convinient to calculate the work done by graphical method.

Before reaching l_1, Let at some stage a very small extension Δx occurs due to force F which is so small that force F is considered to be constant in Δx. The workdone $F\Delta x$ is equal to the area of the shaded strip. For determining the total workdone, extension l_1 is divided in to very small extensions. The sum of areas of all these strips is equal to the area of triangle OAB which gives the net workdone. Hence

$$\text{Workdone} = \text{Area of } \Delta OAB$$
$$= \frac{1}{2} \times OA \times OB$$
$$= \frac{1}{2} \times l_1 \times F_1$$

This work is appeared as strain energy inside the wire. so

$$\text{Strain Energy} = \frac{1}{2} l_1 F_1 \quad \text{——— (A)}$$

STRAIN ENERGY IN TERMS OF ELASTIC MODULUS

If A be the area of the wire of length L having a modulus of elasticity E then

$$E = \frac{\sigma}{\epsilon} = \frac{F}{A} \div \frac{l_1}{L}$$

$$E = \frac{FL}{A l_1}$$

$$\Rightarrow F = \frac{EA l_1}{L} \quad \text{——— (B)}$$

Using the value of F from eq (B) in equation (A)

$$\text{Strain Energy} = \frac{1}{2} \times \frac{EA\,l_1}{L} \times l_1$$
$$= \frac{1}{2}\frac{EA\,l_1^2}{L}$$

If extension increases from l_1 to l_2, the work-done will be equal to the area of trapezium. This method is applicable for elastic and non elastic region of the curve. For O to G extension, the work is equal to the area of ΔOHG

ELECTRICAL PROPERTIES OF SOLIDS

Electrical properties of solids mean their ability to conduct electric current. The response of various materials is quite different and can be clearly distinguished on the basis of their conductivity, i.e

(a) Solids like metals possess a high conductivity of the order of $10^7 (\Omega m)^{-1}$ are called **conductors**

(b) At the other extreme, solids like wood, diamond etc have very low conductivities ranging b/w 10^{-10} to $10^{-20} (\Omega m)^{-1}$ are called insulators.

(c) Solids like Silicon and Germinium have an intermediate conductivities from 10^{-6} to $10^{-4} (\Omega m)^{-1}$ are termed as **Semiconductors.**

The conventional free electron theory based on Bohr's atomic model fails to explain completely the wide variation in the behaviour of above three materials but energy band theory based on the wave mechanical model is quite successful in this respect.

http://www.phycity.com

ENERGY BAND THEORY

Electrons in an isolated atom are bound to its nucleus and can only have distinct energy levels. In case of solid material comprises of N atoms very close to each other. These levels are broken in to number of sub levels under the influence of interatomic forces and are called **states**.

These permissible energy states are closely spaced and appear to be a continuous energy band.

A brief description of different energy bands is as follow:

FORBIDDEN ENERGY BAND

Def: The range of energy states in between any two permissible energy states which are not occupied by electrons is called forbidden energy band and the energy states are called forbidden energy states.

VALENCE BAND

Def: The band occupying the outermost shell of an atom is called valence band. It may either be completely filled or partially filled and can never be empty.

VALENCE ELECTRONS

Def: The electrons occupied by the outermost shell of an atom are called valence electrons.

CONDUCTION BAND

Def: The band above the valence band that contains free electrons which are responsible for the flow of electric current through solids is called conduction band. It may either be empty or partially filled with electrons.

http://www.phycity.com

Chapter : 17
Physics of Solids

CONDUCTIVE OR FREE ELECTRON

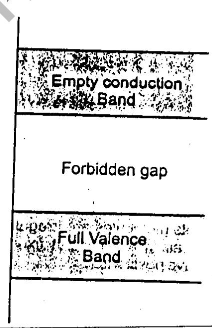
Def # The electrons occupied by the conduction band are called conductive or free electrons

The band below the valence band are normally completely filled and hence play no role in the conduction process.

Now we will explain the behaviour of different solids on the basis of band theory.

INSULATORS

Def # Those materials in which valence electrons are bound tightly to their atoms and are not free are called insulators.



The band features of such materials is that they have

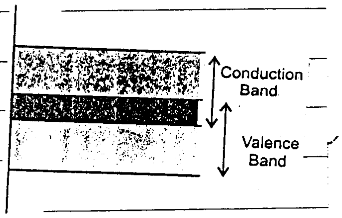
(a) an empty conduction band
(b) a full valence band
(c) a wide energy gap of several eV b/w conduction and valence band.

CONDUCTORS

Def # Those materials which have plenty of free electrons for electrical conduction are called conductors

OR

Those materials in which valence and conduction band are overlaping in such a way that their is no physical distinction b/w them are called conductors.



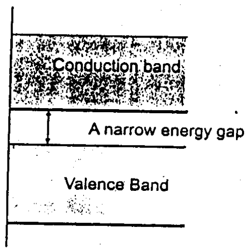
In conductors

(a) Conduction band is partially filled
(b) valence band is partially filled
(c) A narrow forbidden gap of the order of 1eV

http://www.phycity.com

between valence band and conduction band.

SEMICONDUCTORS



 # Def # Those materials which have a very narrow gap between their filled valence band and empty conduction band at a very low temperature (0K) are called semiconductors.

If the temperature of such material is increased above 0K, The thermally excited electrons jump from valence in to Conduction band after Crossing the narrow forbidden gap by leaving vacancies in the valence band which are referred as hole and behave's like a positive charge. The Conduction increases gradually and the material becomes a semiconductor at room temperature.

TYPES OF SEMICONDUCTOR

There are two main types of a semiconductor.

1- Interinsic semiconductor
2- Exterinsic semiconductor

INTERINSIC SEMICONDUCTOR

 # Def # A semiconductor in its extremly pure form without any impurity is called interinsic semiconductor.
e.g Germanium & Silicon

#EXTERINSIC SEMICONDUCTOR

 # Def # The doped semiconductor is called exterinsic semiconductor.

OR

A semiconductor to which some impurity is added to obtain the desired conduction property is called exterinsie semiconductor.

DOPING

 # Def # A process in which a certain amount of

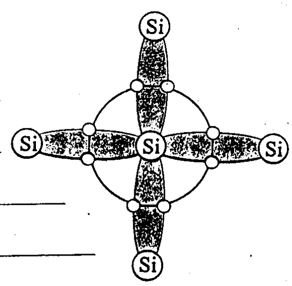
http://www.phycity.com

Some suitable element is mixed as impurity inside the lattice of an intrinsic semiconductor to enhance its conductivity is called doping.

Normally one atom of impurity is added in 10^6 atoms of interinsic semiconductors like Si & Ge.

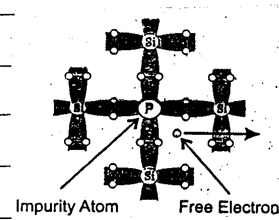
STRUCTURE OF INTRINSIC SEMICONDUCTOR

The intrinsic semiconductors like Germanium and silicon lie in the fourth group of the periodic table and hence have four valence electrons in their outermost shell. In crystal form the atoms are arranged in such a way that each atom is surrounded by its four equidistant neighbouring atoms. In order to make a stable structure, the centeral atom shares its four electron to its four neighbouring atoms through covalent bonds. As a result, each atom complete its outer most shell with eight electrons. As electrons are strictly bound to their nucleus due to these covalent bonds. That is why the conductivity of pure semiconductor is very low.



N-TYPE SEMICONDUCTOR

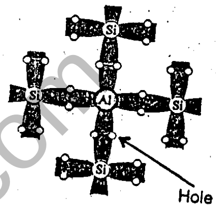
When a silicon crystal is doped with a pentavalent element, e.g., Arsenic, Antimony or phosphorous etc, four valence electrons of the impurity atom form covalent bond with the four neighbouring Si atoms, while the fifth valence electron provides a free electron. Such a doped or extrinsic semiconductor is called n-type semiconductor.



http://www.phycity.com

Def # The germanium or silicon crystal formed after adding a pentavalent impurity (phosphorous, antimony) is called N-type semiconductor. Electrons are majority charge carriers in such crystals.

P-TYPE SEMICONDUCTOR



When a silicon crystal is doped with a trivalent impurity, e.g., aluminium, boron, gallium or indium etc. three valence electrons of the impurity atom form covalent bond with the three neighbouring Si atoms but an electron vacancy is left in the bond of fourth neighbouring atom. Such vacancy of electron is called hole and such a semiconductor is called p-type semiconductor.

Def # The single crystal of germanium or silicon, formed after adding a trivalent impurity (aluminium, indium) is known as p-type semiconductor. Holes are the majority charge carriers in such a semiconductors.

DONOR IMPURITY

Def # A pentavalent impurity like arsenic that readily donates a free electron to a germanium or silicon crystal is called donor impurity.

ACCEPTOR IMPURITY

Def # A trivalent impurity like Indium that accept a free electron from a germanium or silicon crystal by creating a hole is called an acceptor impurity.

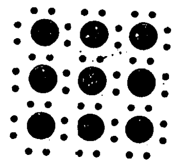
Donor Impurity is used in the formation of N-type.
Acceptor Impurity is used in the formation of p-type materials.

http://www.phycity.com

Visit us at
http://WWW.PHYCITY.COM

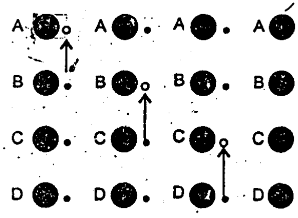
ELECTRICAL CONDUCTION BY ELECTRONS AND HOLES IN SOLIDS

Consider a crystal lattice of Germanium or Silicon in which the valence electrons in the form of dots are strictly bound to their +vely charged core (circles) by Covalent bond as shown in fig.



At room temperature (27°c), these valence electrons are thermally agitated to such an extent that the covalent bonds are broken as a result of which valence electrons get free by leaving behind a vacancy called hole. Thus the breaking of Covalent bond results an electron hole pair.

In order to study the flow of electrons and holes inside a semiconductor, Let us consider the rows of silicon (Si) atoms in a Crystal lattice as shown in fig.

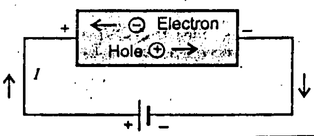


Initially a hole is present in the valence shell of atom A. Due to the deficiency of electron, the Core of atom A has a net +ve charge. It attracts an electron from its neighbouring atom B by shifting hole towards B. Similarly core of atom B captures an electron from C by leaving a vacancy in C. The process continues and the hole is finally shifted to atom D. Hence it is observed that the motion of holes is always opposite to the motion of electrons in a semiconductor. The case which is discussed above is an ideal one. Actually the motion of electrons and holes is random. It is due to the fact that the +vely charged core of the atom can attract electron from any of its neighbouring atom.

http://www.phycity.com

Date: / /

When a battery is applied to a semiconductor, electrons and holes start moving in the presence of electric field set up across the semiconductor. Electrons flow towards the +ve terminal of the battery while holes are drifted towards the -ve terminals. The net current inside the semiconductor is equal to the sum of currents flowing due to electrons and holes.

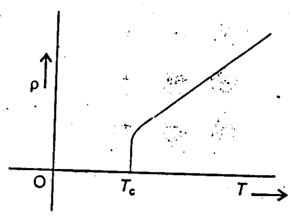


SUPERCONDUCTORS

Def # Those materials whose resistivity becomes equal to zero below a certain temperature (T_c) are called superconductors.

EXPLANATION

Since we know that resistivity ρ of the materials varies significantly with their temperature. The graph plotted b/w resistivity ρ and temperature T is as shown in the fig.



The curve shows that the resistivity of the material is decreased with the decrease in temperature till at a temperature T_c where it drops to zero.

CRITICAL TEMPERATURE

Def # A temperature at which the value of resistivity of a material falls to zero is called critical temperature.

At this temperature as the resistivity of the material vanishes therefore no heat energy is dissipated and the current can exist for indefinite time without a source of emf.

HISTORICAL BACKGROUND

The first ever discovery of superconductor was made by Kmaerlingh Ones in 1911. He proved experimently that mercury loses its resistivity below 4.2K and behaves like a superconductor. Metals like Aluminium ($T_c = 1.18K$), Tin (3.72K) and lead ($T_c = 7.2K$) are also super conductor at low temperature. In 1986 a new class of ceramic material show super conductivity at 125K.

HIGH TEMPERATURE SUPER CONDUCTOR

Def # Any superconductor having a critical temperature above 77K (Boiling point of liquid Nitrogen) is called high temperature superconductor.

Professor Yao Lian's Lee recently discovered a super conductor at 163K or -110°C in form of a complex crystalline structure known as Yatrium Barium Copper oxide ($YBa_2Cu_3O_7$) at Cambridge university.

APPLICATIONS OF SUPERCONDUCTORS

Super conductors can be used in

(a) Magnetic Resonance Imaging (MRI)
(b) Magnetic Levitation trains
(c) powerful but small electric motors
(d) Fast Computer Chips

NOTE # # MAGNETIC RESONANCE IMAGING

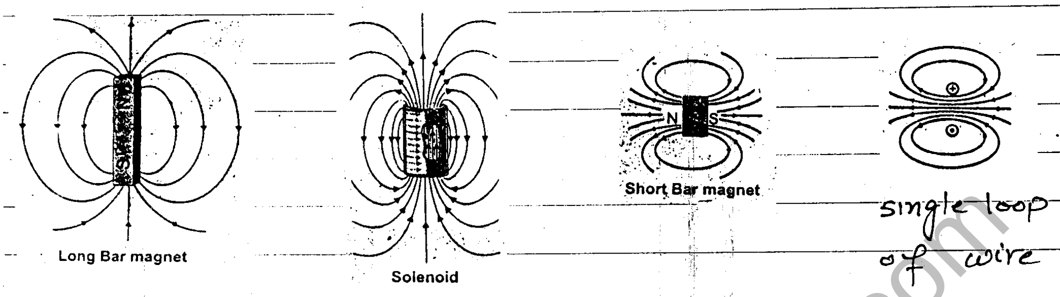
A technique which is used to identify the tumour and inflamed tissues through images developed by computer processing with the help of strong magnetic field provided by a superconductor is called magnetic resonance imaging.

MAGNETIC PROPERTIES OF SOLIDS

The magnetic field produced by a bar magnet and that of moving charges has made it possible to trace the origin of magnetic properties of solid materials. It is experimently proved that the field

http://www.phycity.com

of long bar magnet and that of solenoid is similar. The same feature is observed b/w the fields of single loop of wire and that of short bar magnet as shown below.



AMPERE'S VIEW

According to Ampere, The magnetic effects produced in solids are due to the flow of electric Current through solids. This idea was not accepted till the discovery of atomic structure.

LATEST VIEW

According to the recent view, the magnetic effects produced inside solids are due to orbiting and spinning motion of electrons inside an atom. The sum of both these fields results a net field. The magnetic fields due to the flow of Current in orbiting motion along with that of spinning of electron may enhance or cancel the effect of each other inside an atom.

MAGNETIC DIPOLE

Def # An atom possessing a resultant magnetic field such that it behaves like a tiny magnet is called magnetic dipole.

Hence it is concluded that the magnetism inside a solid material is only due to spin and orbital motion of electrons. The charged nucleus has also

http://www.phycity.com

a very negligible magnetic field due to its spinning motion. It is impossible to get an isolated north pole i.e. one side of current loop. It is an experimental reality that north pole cannot be separated from South pole.

TYPES OF MAGNETIC MATERIALS

On the basis of fields produced by the orbital and spinning motion of electrons, we can divide the materials in to following three types.

1- # PARAMAGNETIC SUBSTANCES

Def # The substances in which orbits and spin axes of the electrons in an atom are so oriented that their magnetic fields support each other and the atom behaves like a tiny magnet are called paramagnetic substances.

2- # DIAMAGNETIC SUBSTANCES

Def # The substances in which magnetic fields produced by orbital and spin motion of electrons add up to zero are called diamagnetic substances.
e.g water, Copper, bismuth, Antimony etc.

3- # FERROMAGNETIC SUBSTANCES

Def # Substances in which atoms cooperate with each other in such a way so as to exhibit a strong magnetic effects are called ferromagnetic substances. e.g. Fe, Ni, Alnico etc.

DOMAIN

A small region that exists inside a ferromagnetic material having a macroscopic size of the order of millimeters or less but large enough to contain 10^{12} to 10^{16} atoms is called domain.

http://www.phycity.com

Date: P # 26

BEHAVIOUR OF DOMAIN

Inside a domain, the magnetic fields produced by all the spinning electrons are parallel to each other and it behaves like a tiny magnet with its own north and south pole. These domains are randomly oriented inside an unmagnatised iron such that the net magnetic field of a sizeable specimen is equal to zero. If now the specimen is placed inside the magnetic field of a solenoid, the domains are lined up parallel to the external field of solenoid as shown in fig.

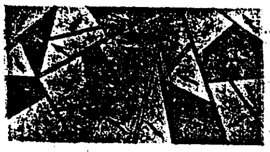


Fig 17.16 Magnetic domains within an unmagnetized ferromagnet

ELECTROMAGNET

 # Def # The combination of a solenoid and iron specimen (core) in which the entire specimen is saturated (domains are aligned) to get a strong magnetic effect is called electromagnet.

SOFT MAGNETIC MATERIAL

 # Def # A material in which domains are easily oriented on applying an external magnetic field and also readily return to their original random position on the removal of external field are called soft magnetic material e.g. core used in electromagnet and transformer.

HARD MAGNETIC MATERIAL

 # Def # A material in which its domains are oriented to order by a very strong external

http://www.phycity.com

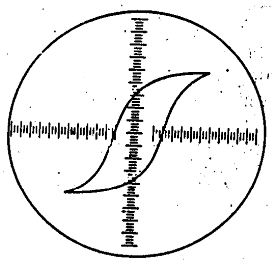
field and once oriented retain the alignment is called hard magnetic material. e.g. permanent magnet, Alnico V etc

CURIE TEMPERATURE

Def # A temperature at which the domains inside a ferromagnetic material begin to lose their orderliness due to their increased thermal motion is called Curie temperature.
The Curie temperature for iron is 750°C

HYSTERESIS LOOP

When a ferromagnetic specimen such as an iron bar is placed inside an alternating current solenoid then for +ve peak value the specimen magnatises in one direction and for -ve peak value it will be magnatised in opposite direction. Thus for a complete AC cycle, the speciman undergoes a complete cycle of magnatisation.



Def # The curve that is plotted on CRO b/w flux density B and magnatization of specimen for different values of magnatizing current of the solenoid is called hysteresis loop.

The main features of such curve are as under.

1- # HYSTERESIS #

OA is the portion of the curve obtained by increasing the magnetizing current and AR is the portion of the curve when the current is decreased.

http://www.phycity.com

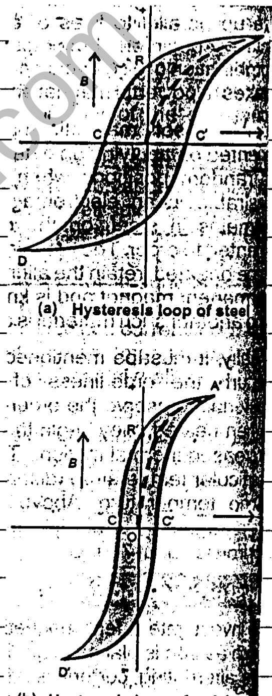
Def

The phenomenon in which the value of flux density for any value of current is always greater when the current is decreasing than one the current is increasing is known as hysteresis.

Hence magnetism lags behind the magnatising current.

2- # SATURATION

The increase in the value of flux density from zero to its maximum value is called saturation and the specimen is said to be saturated.


(a) Hysteresis loop of steel
(b) Hysteresis loop of soft iron
OR = Retentivity
OC = Coercivity

3- # REMANENCE OR RETENTIVITY

The point R on the curve shows the remanence or retentivity. which means that the specimen is strongly magnatised due to the tendency of the domains to stay in line, once they have been aligned.

4 # COERCIVITY

#Def# The mechanism due to which the magnatization of a material falls to zero when the magnatizing current is reversed and increased is called Co-ercivity and the applied current is called coercive current and is denoted by C.

The coercivity of steel is greater than that of iron because more current is needed to demagnatize steel.

Once the material is demagnatised, its magnatisation curve never passes through

http://www.phycity.com

origin but form a closed loop ACDCA which is called hysteresis loop.

5— # AREA OF THE LOOP #

Area of the hysteresis loop is the amount of energy which is required to magnatize and demagnatize the material in each cycle. It is also called hysteresis loss.

HYSTERESIS LOSS

Def # The energy needed to do work against the internal friction of domains and dissipated in the form of heat is called hysteresis loss. It is equal to the area of hysteresis loop.

As more energy is required to magnatize or demagnatize the hard magnetic material like steel as compared to soft magnetic material like iron, that is why energy dissipated per cycle for iron is less than for steel

Those materials having high retentivity and large coercivity are suitable to make permanent magnet while the core of electromagnet used for alternating current where the specimen undergoes magnetization and demagnetization have a very narrow curves of small area to minimize the waste energy.

END

http://www.phycity.com