Lecturer Physics
M. Phil Physics, M. Ed
(Gold Medalist)

Chapter = 17

Physics of Solids

What is Solid state physics?"The branch of Physics which deals with structure & properties of solids is called solid state physics".

Difference b/w crystalline, amorphous and polymeric solids.

Crystalline solids	Amorphous solids	Polymeric solids
Those solids in which there is regular arrangement of atoms or molecules are called crystalline solids.	The word amorphous means "without form or structure". So, "such solids in which there is no regular arrangement of molecules are called amorphous solids"	Such type of solids which are more or less solid materials with a structure which is intermediate b/w order and disorder are called polymeric solids.
For examples copper, NaCl, zirconia's etc.	For example ordinary glass	For example Plastics, synthetic rubber, polythene and nylon.
Properties of crystalline solids	**Properties of amorphous solids**	**Properties of polymeric solids**
i. The atoms, molecules or ions in crystalline solids are in state of vibratory motion about fixed points i. Cohesive force b/w atoms maintain strict long range order ii. They have definite melting point	i. They have no definite melting point ii. On heating it gradually soften into paste and becomes very viscous liquid at 800°C	i. Polymeric solids consists wholly or partly combination of carbon with oxygen, hydrogen, nitrogen or nonmetallic elements. Natural rubber $(C_5H_6)_n$. ii. The materials have low specific gravity compared to lightest of metals.

A crystalline solid consists of three dimensional patterns that repeat itself again and again.
What is Specific gravity? The ratio of density of substance to density of a reference substance (usually water) is called specific gravity.
What is Unit cell? The smallest three dimensional basic structures is called unit cell.
What is Crystal lattice? The whole structure which is obtained by the repetition of unit cell is called crystal lattice. e.g NaCl has cubic.
Practice MCQs

Describe Mechanical properties of solids.

What is Deformation? Any change which is produced in length, volume or shape of object when external force is applied is called deformation. For example when we hold a rubber ball in our hand it compresses shape and volume changes.
What is Elasticity? The ability of a body to return to its original shape when stress is removed is called elasticity.
What are stress and strain? Write their formulas and units as well as types.

Stress: The force applied on unit area to produce change in length, volume or shape is called stress. Its unit is Nm^{-2}

$stress = \frac{Force}{Area} = \frac{F}{A}$ And dimension is $[ML^{-1}T^{-2}]$

Types of stress: There are three types of stress

i. **Tensile stress**: A stress that changes the length of body is called tensile stress
ii. **Volumetric stress**: A stress that changes the volume of body is called volumetric stress.
iii. **Shear stress**: When the stress changes the shape of body is called shear stress.

Strain: The measure of deformation of solid material when stress is applied on it is called strain. It has no unit.

Types of strain

i. **Tensile strain**: Fractional change in length is called tensile strain which is $=\Delta L/L$
ii. **Volumetric strain:** fractional change in volume is called volumetric strain which is $=\Delta V/V$
iii. **Shear strain**: Change in shape by shear stress, it is in angle , y=tan =Δa/a,for small values y=

State Hook's law

Within elastic limit, stress is directly proportional to strain. Stress ∝ strain, stress=constant (strain)

What is elastic modulus? Give its types.

Elastic modulus or modulus of elasticity: The ratio of stress to strain remains constant which is called elastic modulus or modulus of elasticity. Its unit is Nm^{-2} or Pascal.

Types of modulus of elasticity

i. **Young's modulus**: The ratio of tensile stress to tensile strain is called young modulus. $Y = \frac{\text{tensil stress}}{\text{tensile strain}} = \frac{F/A}{\Delta l/l} = \frac{Fl}{\Delta l A}$. Its unit is Nm^{-2} or Pascal.
ii. **Bulk modulus**: The ratio of volumetric stress to volumetric strain is called bulk modulus. $B = \frac{\text{volumetric stress}}{\text{volumetric strain}} = \frac{F/A}{\Delta V/V} = \frac{FV}{\Delta VA}$. Its unit is Nm^{-2} or Pascal.
iii. **Shear modulus:** The ratio of shear stress to the shear strain is called shear modulus. $G = \frac{\text{shear stress}}{\text{shear strain}} = \frac{F/A}{\tan\theta}$, it is also called modulus of rigidity. Its unit is Nm^{-2} or Pascal.

Draw a stress strain curve for ductile material. Discuss the term related to this tensile test.

Tensile test: In this test metal wire is extended at a specified deformation rate and stresses generated in the wire during deformation are continuously measured by a suitable electronic device fitted in the mechanical test machine. Force elongation graph for ductile material is shown in fig.
Proportional limit: Proportional limit is the greatest stress
That a material can endure without losing straight line

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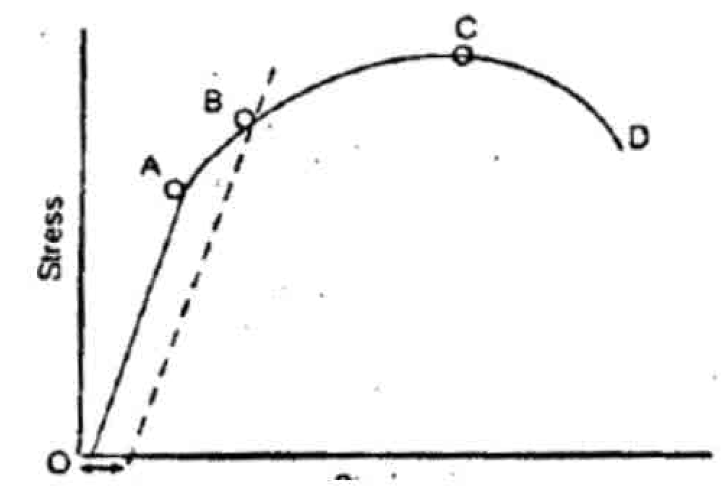


Proportionality between stress and strain. Hooks law applicable.
This limit is from O to An in graph.

Elastic limit: Elastic limit is the greatest stress that a material can endure without any permanent deformation. This limit is from A to B.

Yield stress: Maximum value of applied stress within its elastic limit is called yield stress.

Plasticity: If the stress is increased beyond elastic limit, the specimen becomes permanently changed and does not regain its original state even if applied stress is removed which is called plasticity.

UTS (ultimate tensile stress): The maximum stress that a material can withstand is called UTS.

Fracture stress: Once UTS is cross, the material breaks at this point and is called fracture stress.

What are ductile and brittle substances? Give examples.

Ductile substance: "The substances which undergo plastic deformation until they break are called ductile substance" e.g. lead copper.

Brittle substance: "The substances which break just after the elastic limit is reached are called brittle substance". Like glass, high carbon steel etc.

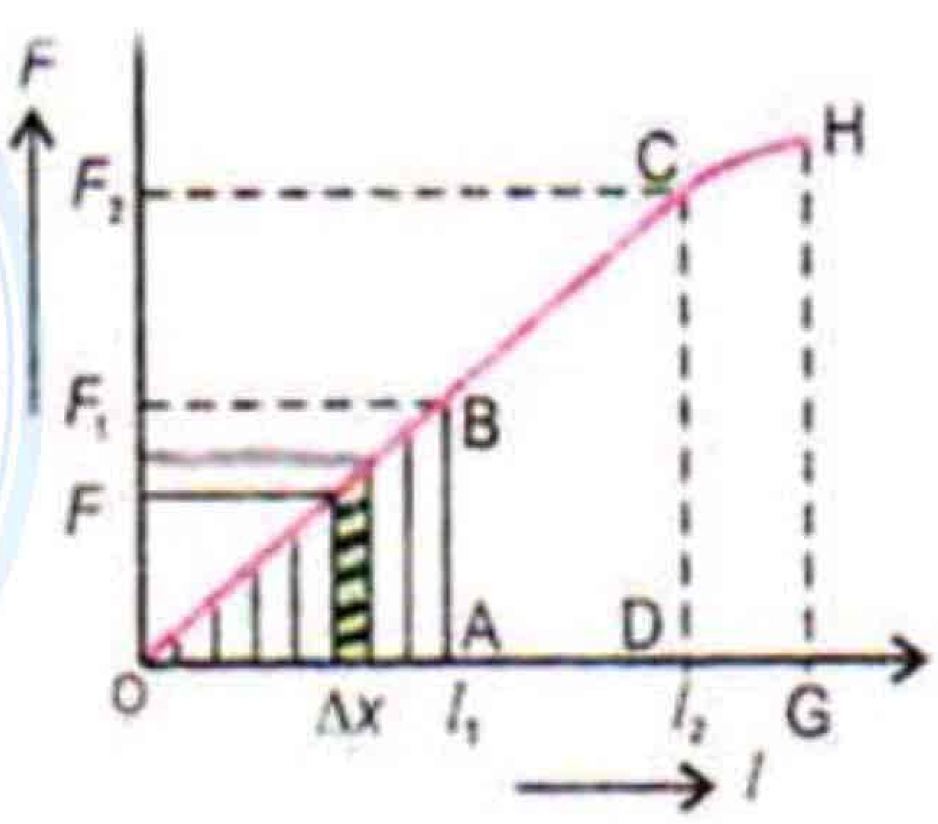
What is strain energy? Derive the relation for strain energy in deformed material from graph.

Strain energy: "The work done in deforming the material which is stored in the form of potential energy is called strain energy".

$$\text{Strain energy} = \frac{1}{2}\left[\frac{EA * l_1^{2}}{L}\right].$$

Explanation: Consider a wire whose one end is attached to the fixed support and stretched vertically connected 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 is plotted b/w extension l and stretching force F.

Work can be calculated by area under the force extension graph. Let us find the work done on the wire when extension is l_1 and force is F_1.



$$\text{Work done} = \text{Area of } \Delta AOAB$$

$$W = \frac{1}{2}(OA)(AB)$$

$$W = \frac{1}{2}(F_1)(l_1) = \frac{1}{2}F_1 l_1$$

This work is stored in the form of potential energy in the wire.

$$P.E = \frac{1}{2}F_1 l_1 \text{ ---------------(1)}$$

Strain energy in terms of elastic modulus: The energy can be calculated in terms of elastic modulus.

$$E = \frac{Stress}{Strain} = \frac{F_1/A}{l_1/L} = \frac{F_1 L}{A l_1}$$

$$F_1 = \frac{EAl_1}{L}, \text{ putting in equation (1)}$$

$$P.E = \frac{1}{2}\left[\frac{EAl_1}{L}\right] l_1 =$$

$$P.E = \frac{1}{2}\left[\frac{EAl_1^2}{L}\right], \text{This is the result for strain energy in deformed material.}$$

Asad Abbas
Lecturer Physics
M. Phil Physics, M. Ed
(Gold Medalist)

DESCRIBE ELECTRICAL PROPERTIES OF SOLIDS

There are three types of solids according to the conduction ability.

Conductors	Insulator	Semiconductor
The substance which can easily conduct electricity having conductivity **10^7 $\Omega^{-1}m^{-1}$** e.g. metals like copper gold, silver etc.	The materials have very low conductivity of ranging **10^{-20} to 10^{-10} $\Omega^{-1}m^{-1}$** like wood, plastic, glass etc	The materials have intermediate conductivity ranging from **10^{-6} to 10^{-4} $\Omega^{-1}m^{-1}$** like Ge, Si etc.

Multiple choice questions

1	SI unit of strain is	N/m2	N/m	Nm	**No unit**
2	The ratio of stress to strain is called	Electricity	Resistivity	Conductivity	**Elastic modulus**
3	The conductivity of material is of the order of	10^1 (ohm m)-1	10^{10} (ohm m)-1	**10^7(ohm m)-1**	10^{15} (ohm m)-1
4	The substance with conductivity of the order of 10-6 (ohm m)$^{-1}$ to 10-4 (Ωm)$^{-1}$	Conductor	Insulator	**Semiconductor**	Super conductor
5	Shear modulus is expressed as G=?	$\frac{\tan\theta}{F/A}$	$\frac{\tan\theta}{A}$	**$\frac{F/A}{\tan\theta}$**	$\frac{\tan\theta}{F}$
6	The resistivity of conductor are of	10^3(Ωm)-1	10^7(Ωm)	**10^{-7}(Ωm)**	10^{-6}(Ωm)-1
7	The SI unit of stress is the same that of	Momentum	**Pressure**	Force	Length
8	Nm^{-2} is also called	Tesla	Weber	**Pascal**	Gauss
9	Dimension of strain are	[L^2]	[L^{-2}]	[$ML^{-1}T^{-2}$]	**No dimension**
10	The atoms, ions and molecules of crystalline materials maintains their long range order due to	Adhesive forces	**Cohesive forces**	Electrostatic force	Van der wall forces
11	The substance with conductivity of the order of	Conductor	**Insulator**	Semiconductor	Super conductor

	10^{-10} (ohm m)-1 to 10^{-20} (Ώm)-1				
12	Glass and high carbon steel are example of	Ductile substance	**Brittle substance**	Soft material	Hard material
13	Reciprocal of bulk modulus is	Elasticity	Young modulus	**Compressibility**	Shear modulus
14	Substance which break just after the elastic limit is reached are called	Ductile substance	Hard substance	Soft substance	**Brittle substance**
15	The ratio of applied stress to volumetric strain is called	Young modulus	Shear modulus	Tensile modulus	**bulk modulus**
16	When a stress changes the shape of a body it is called	Volumetric stress	**Shear stress**	Tensile stress	Compressional stress
17	The ability of a body to return to its original shape is called	Strain	Stress	**Elasticity**	Plasticity
18	Which type of solids have definite melting point are called solids	**Crystalline**	Amorphous	Both A&B	None of these
19	The stress that produces in shape is	Tensile stress	**Shear stress**	Volume stress	All of these
20	Which one of the following is crystalline solid	**Zirconia**	Glassy solids	Natural rubber	Polystrene
21	The young modulus of steel is	$\underline{20x10^{11}\ Nm^{-2}}$	$3.9x10^{-9}\ Nm^{-2}$	$2x10^{9}\ Nm^{-2}$	$1.5x10^{9}\ Nm^{-2}$
22	A solids having regular arrangements of molecules	Britlle	**Crystalline**	Amorphous	Polymeric
23	There are--- different crystal systems based on geometrical arrangement of atoms	2	5	**7**	9

What is band theory of solids? Differentiate b/w conductor insulator and semiconductor on the basis of Band theory of solids.

Concept of Band theory of solids was given by Felix Bloch in 1928.

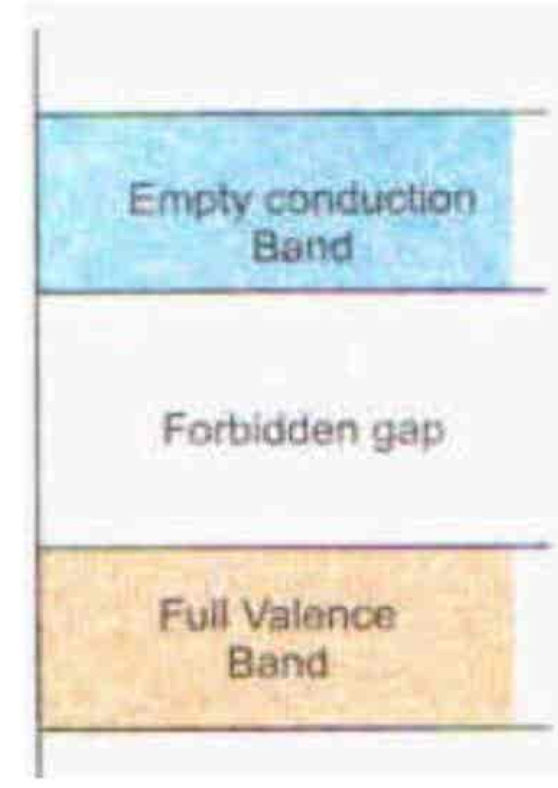
Energy band/states: A group of such energy sublevels when the number of atoms are brought together and interacts one another and each energy level splits up into many sublevels are called energy band. The Theory which explain the difference b/w conductor, insulator and semiconductor on the basis this energy band or states is called band theory of solids. There are three types of bands

Forbidden band: The energy bands are separated by gaps in which there are no electrons. Such energy gaps are called forbidden band.

Valence band: The electrons in the outermost shell of an atom are called valance electrons. Therefore, the energy band occupied by valance electrons is called the valance band.

Conduction band: The band above the valence band and in which electrons move freely and conduct electric current is called conduction band.

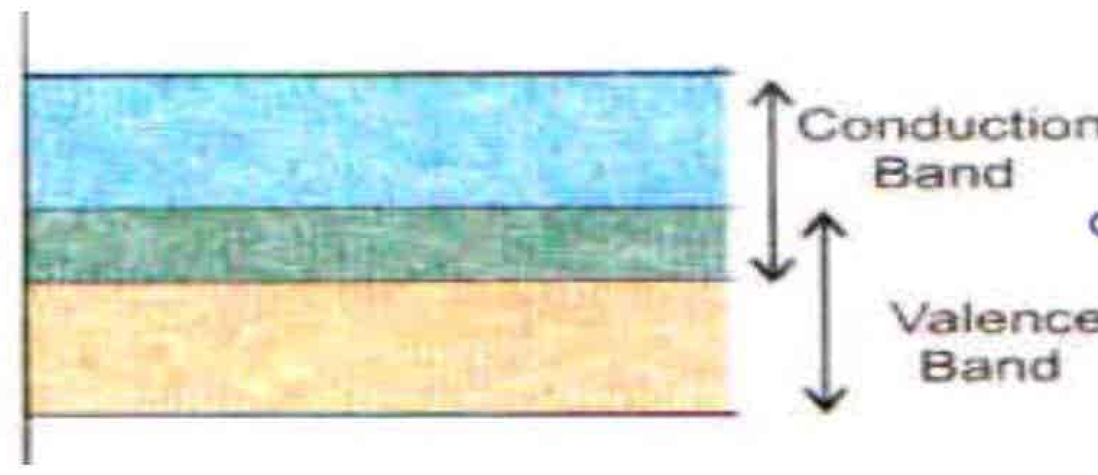
Insulators: Insulators are those materials in which valence electrons are bound very tightly to their atoms having



i. An empty conduction band
ii. A filled valance band
iii. A large energy gap of several eV

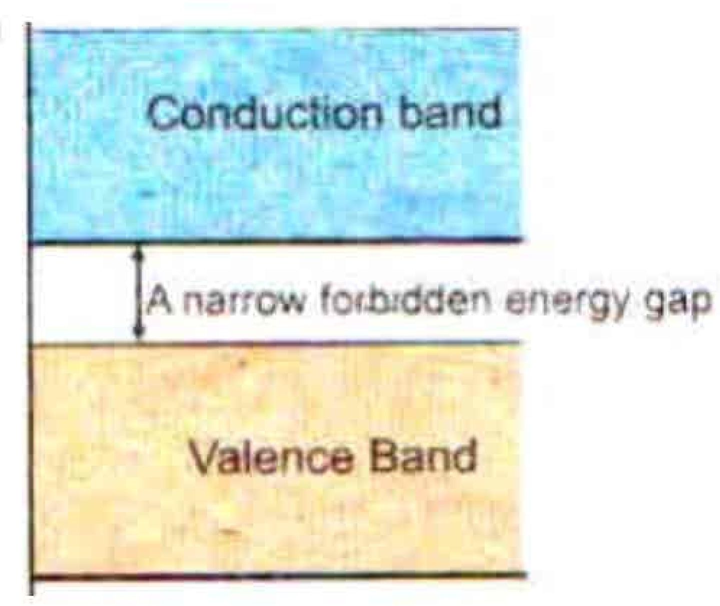
Conductors: Conductors are those materials in which have large number of free electrons having

i. Partially filled conduction band
ii. Partially filled valance band
iii. No energy gap



Semiconductor: Semiconductors have electrical property lies b/w insulator and conductors having

i. Partially filled valance band
ii. Partially filled conduction band
iii. A narrow energy gap(1eV)



At 0 K semiconductor is pure insulator and at room temperature Ge and Si crystal is semiconductor.

What is Intrinsic and extrinsic semiconductor? How P type and N type semiconductors are formed?

Intrinsic semiconductor: A semiconductor in its extremely pure form is called intrinsic semiconductor as pure Si or Ge.
Extrinsic semiconductor: A doped and impure semiconductor is called extrinsic semiconductor. Like p type or n type substances.
Doping and dopant: The process of adding the small impurity atom in pure semiconductor is called doping. And impurity materials itself is called dopant.
The impurity atoms are added in semiconductor in the ratio 1 to 10^6 atoms.
Types of Extrinsic Semiconductor: There are two types of extrinsic semiconductor
(i): N- type Semiconductor: The semiconductor which is formed by adding pentavalent impurity to a pure semiconductor is called N-type semiconductor.
Pentavalent impurity: An atom belongs to 5^{th} group have five valence electrons like antimony, phosphorous and arsenic etc.
(ii) P- type semiconductor: The semiconductor which is formed by adding trivalent impurity to pure semiconductor is called P-type semiconductor.
Trivalent impurity: An atom belonging to third group has three valence electrons like aluminum, boron, gallium, and indium.
Acceptor and donor impurity:
As pentavalent impurity donates a free electrons so it is called donor impurity

Trivalent impurity accepts a free electron so it is called accepter impurity.

Electrical conduction by electrons and holes in semiconductor

When a battery is connected to a semi-conductor, it establishes an electric field across it due to which a directed flow of electrons and holes takes place. The electrons drift towards the positive end whereas the holes drift towards the negative end of the semiconductor. The current flowing through the semiconductor is carried by both electrons and holes.

Multiple choice questions

1	To make a n type semiconductor a pure SI should be doped with atoms of	Ge	**P**	C	Al
2	The substance which have partially filled conduction band are called	Insulator	**Semiconductor**	Conductor	Super conductor
3	When a silicon is doped with pentavalent element it becomes	P type semiconductor	**N type semiconductor**	Intrinsic semiconductor	Extrinsic semiconductor
4	What type of impurity is to be added to the semiconductor material to provide holes	Mono valent	**Trivalent**	Tetra valent	Pentavalent
5	In n type materials minority carrier are	Free electrons	**Holes**	Protons	Mesons
6	A well-known example of an intrinsic semi conductor is	**Germanium**	Phosphorus	Aluminium	Cobalt
7	Majority carriers in p type substance	**holes**	Neutrons	Electrons	Positrons
8	Majority carriers in n type substance	Protons	Neutrons	**Electrons**	Positrons
9	If the conductivity of a material is high then it is	An insulator	A semi-conductor	**A good conductor**	A super conductor
10	Which of the following has least energy gap ?	**Conductor**	Insulator	Semi-conductor	None of these
11	A substance having empty conduction band is called	Conductor	**Insulator**	Semi-conductor	All of these
12	According to band theory of solids the band in atom containing conductive electrons is	**Conduction band**	Valence band	Forbidden band	First conduction then forbidden band
13	Which pair belongs to acceptor impurity	Arsenic, phosphrous	**Boron, gallium**	Antimony, indium	Arsenic, antimony
14	Which one is pentavalent?	Boron	Gallium	**Antimony**	Indium
15	At 0k semiconductor are	Conductors	Insulators	Perfect	**Perfect**

				conductor	**insulator**

Write a note on Super conductors.

Superconductor: "The materials whose resistivity becomes zero below a certain temperature are called superconductors".

Critical temperature: The temperature at which the resistivity of a material becomes zero is called critical temperature.

Superconductivity: "The process of reducing the resistance of material with low temperature to immeasurable low value is called superconductivity".

As resistance of material is zero, so no energy is dissipated.

First superconductor was discovered by Kmaerlingornes 1911.

Critical temperature for different materials: Mercury= 4.2 K, aluminum= 1.18 K, Tin= 3.72 K, lead= 7.2 K

Critical temperature of yttrium barium copper oxide ($YBa_2Cu_3O_7$):163 K or -110°C

Uses of superconductor: Superconductors are used in

i. Magnetic resonance imaging(MRI)
ii. Magnetic levitation trains
iii. Powerful electric motors
iv. Faster computer chips

Explain the types of magnet and give their Magnetic properties .

Origin of magnetism: Magnetism is the property of all substance due to their orbital and spin motion of electrons.

Magnetic dipole: An atom in which there is resultant magnetic field behave like a tiny magnet is called magnetic dipole.

Types of magnets: There are three type of magnetic substance

i. Paramagnetic substance
ii. Diamagnetic substance
iii. Ferromagnetic substance

Paramagnetic substance: The substance in which magnetic field produced by the orbital and spin motion of electrons support each other and atoms behave like tiny magnet are called paramagnetic substance. Like Al, Pt, Mn etc.

Diamagnetic substance: The substance in which magnetic fields produced by orbital and spin motion of electrons cancel each other and no resultant field is produced are called diamagnetic substance like Cu, Bi, Sb, atoms of water.

Ferromagnetic substance: The substances in which atoms co-operate with each other in such a way that they show a strong magnetic effect are called ferromagnetic substance. Like iron, nickel, cobalt, Alnico V etc.

Domains: The small magnetized regions in ferromagnetic substance are called domains. They have the microscopic size of 10^{12} to 10^{16} atoms.

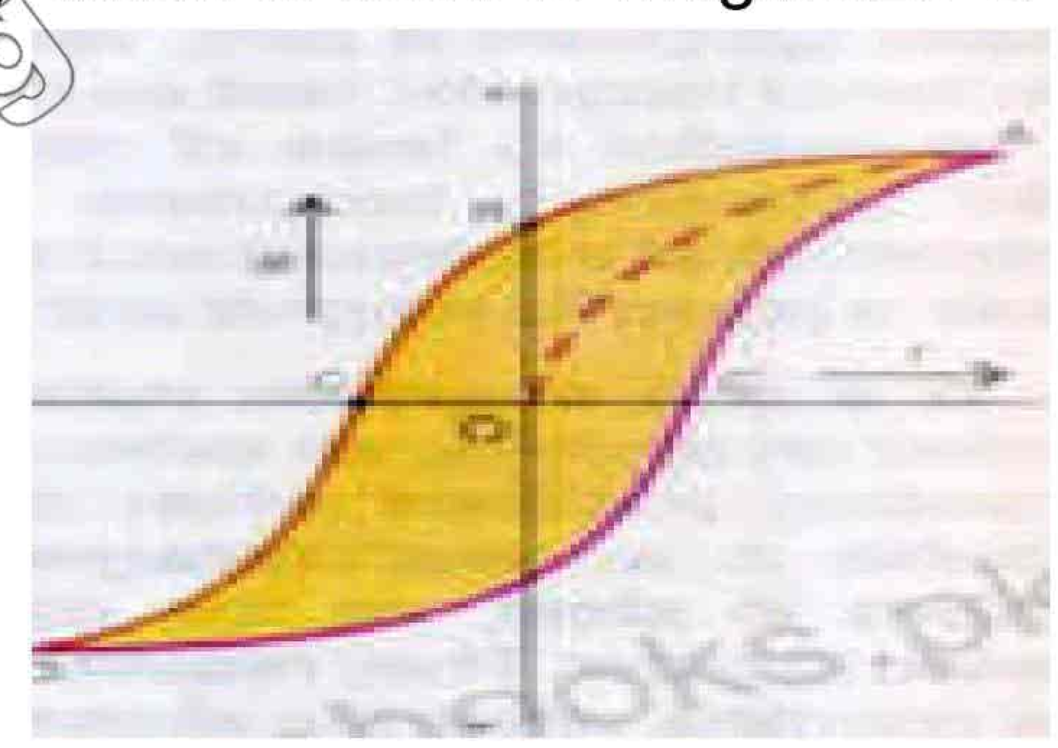
Soft ferromagnetic substance: The ferromagnetic substance whose domains can be easily oriented on applying an external magnetic field and return to original position when field is removed are called soft ferromagnetic substance like iron.

Hard ferromagnetic substance: The ferromagnetic substance whose domains cannot be easily oriented on applying an external magneticfield and return to original position when field is removed are called hard ferromagnetic substance, steel is an example.

Curie temperature: The temperature above which a ferromagnetic substance becomes paramagnetic substance is called Curie temperature. Like curie temp of iron is 750°C.

What is Hysteresis loop. Explain the terms related to hysteresis loop.

Hysteresis loop: The graph b/w flux density and magnetization of specimen of for different values of magnetizing current in the form of loop is called hysteresis loop.
Hysteresis: The value of flux density for any value of current is always greater when the current is decreasing, then when it is increasing, i.e., magnetism lags behind the magnetizing current. This is called hysteresis.
Hysteresis loss: when a ferromagnetic substance is placed in an alternating current solenoid, the energy is needed to magnetize or demagnetize the material during each cycle of magnetizing current. This energy is need to do work again frictions of domains, this work is loss as heat which is called hysteresis loss. It is useful to decide either the material is suitable for construction of transformer
Saturation: When the magnetic flux density increase from zero to maximum value, then is magnetically saturated.
Remanence or retentivty: When the current is reduced to zero, material is still remains magnetized due to tendency of domains to stay partly in line, this property is called remanence.
coercivity and coercive current: Todemagnetize the material, the magnetizing current is reversed and increased to reduce the magnetization to zero. This is known as coercive current and this property is called coercivity.
Coercivity of steel is more than that of iron, as more current is needed to demagnetize it.
Area of loop: The area of loop is proportional to the energy which is used in magnetization, it describe about hysteresis loss, it also describe about the energy which is used to magnetize or demagnetize the material.



- For hard magnetic materials the area of loop is large as compared to soft magnetic materials so energy dissipated per second for iron is less than steel.
- Materials with high retentivity and large coericivity Are most suitable for making permanent magnet.
- The materials with low retentivity and large coercivity are suitable for making core of electromagnet.

Tid bits

- ✓ **Range:** The range of glassy solids is Short range and range of crystalline solids is Long range.
- ✓ **Seven crystal system:** .i. cubic system ii. Tetragonal system.iii. Hexagonal iv.trigonal system. v. rhombic system. vi. Monoclinic vii. triclinic system
- ✓ **Glass** is known as solid liquid because its molecules are irregularly arranged as in a liquid but fixed in their relative positions.
- ✓ Superconductors are alloys that conduct electricity at certain temperature with no resistance.
- ✓ **MRI stands for magnetic resonance imaging**. It uses strong magnetic field produced by super conducting materials for scanning computer processing produces the image identifying tumors and inflamed tissues.
- ✓ **Squids stand for super conducting quantum interference devices**. It is used to detect very weak magnetic field such as produce by brain.
- ✓ Magnet made out of organic materials could be used in optical disks and components in computers, mobile phones, TVs, motors, generators and data storage devices.

Multiple choice questions

1	Squids are to detect very weak magnetic field produced by	Heart	Liver	Tongue	**Brain**
2	MRI use field	Very weak	**Strong**	Weak	Zero
3	MRI used for image identifying of	Tumor	Inflamed	**Both A&B**	None

			tissues		
4	A Bullet train speed can be enhanced upto	300 Km/h	400 Km/h	**500 Km/h**	600 km/h
5	Curie temperature for iron is	450 C	550 C	**750 C**	850 C
6	Soft magnetic material is	**Iron**	Sodium	Steel	Copper
7	Critical temperature for mercury is	7.2 K	**4.2K**	1.18K	3.7k
8	The material below which resistivity of some materials become zero is called	Kelvin temperatur e	**Critical temperature**	Absolute temperature	Limiting temperature
9	Which one is not a ferromagnetic substance?	Cobalt	**Copper**	Nickel	Iron
10	which of the following has the least hysteresis loop area	Steel	Wrought iron	**Soft iron**	Cobalt
11	The substance in which the atoms do not form magnetic dipole are called	Ferromagn etic	Paramagnetic	**Diamagnetic**	Conductor
12	Critical temperature for lead	1.18 K	**7.2 K**	4.2 K	3.72 K
13	Best magnetic material is made up of	**Alnico V**	Iron	Nickel	Cobalt
14	Curi temperature for iron is	0K	570 K	**1023 K**	378 K
15	The substance in which the atoms do not form magnetic dipole are called	Ferro magnetic	Para magnetic	**Diamagnetic**	Conductor
16	The magnetism produced by electrons within an atom is due to	Spin motion	Orbital motion	**Spin motion and orbital motion**	Vibratory motion
17	Critical temperature for Aluminum	**1.18 K**	4.2 K	7.2 K	3.72 K
18	A magnetic field acts charged particle so as to change its	Speed	Energy	**Direction of motion**	All of these
19	Eddy current produced in the core of transformer are responsible for	**Heat loss**	Step up process	Step down process	Induction phenomenon
20	The temperature at which a ferromagnetic material becomes paramagnetic is called	Critical temperatur e	Absolute temperature	**Curi's temperature**	All of these
21	Critical temperature of yttrium barium copper oxide ($YBa_2Cu_3O_7$)	143 K	**163 K**	183 K	110 K
22	The number of atoms in domains of macroscopic size of a ferromagnetic substance are	10^4 to 10^6	10^6 to 10^8	**10^{12} to 10^{16}**	10^{21} to10^{23}

23	At curie temperature iron becomes	ferromagnetic	Diamagnetic	**Paramagnetic**	Super conductor
24	It is used to detect very weak magnetic field such as produce by brain.	Magnetic material	MRI	**SQUIDS**	None
25	Critical temperature for tin	1.18 K	4.2 K	7.2 K	**3.72 K**
26	Which one is not a ferromagnetic substance	Cobalt	**Copper**	Nickel	Iron
27	Magnetism lags behind the magnetization current this phenomenon is called	Saturation	Rententivity	**Hysteresis**	Coercivity
28	The most suitable material for making permanent magnet is	Iron	**Steel**	Aluminum	Copper

Note: Exercise short Questions are solved in Theory of this chapter.

Asad Abbas
Lecturer Physics
M. Phil Physics, M. Ed
(Gold Medalist)

Chapter = 17

Numerical problems

17.1: A 1.25cm diameter cylinder is subjected to a load of 2500kg. Calculate the stress on the bar in mega Pascal's.

Given Data : $d = 1.25cm = 1.25*10^{-2}$ m, $r = d/2 = 1.25*10^{-2}/2 = 0.625*10^{-2}$ m, m = 2500kg, Stress = ?

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{mg}{\pi r^2} = \frac{2500*9.8}{3.14*(0.625*10^{-2})^2} = 200*10^6\,\text{Pa} = 200\,\text{MPa}$$

17.2: A 1.0m long copper wire is subjected to stretching force and its length increases by 20cm. calculate the tensile strain and the percent elongation which the wire undergoes.

Given data : $l = 1m$, $\Delta l = 20cm = 20/100 = 0.20m$, Tensil strain = ? % elongation = ?

$$\text{Tensil strain} = \frac{\Delta l}{l} = \frac{0.20}{1} = 0.20,\ \ \%\,\text{elongation} = \frac{\Delta l}{l}*100 = 0.20*100 = 20\%$$

17.3: A wire 2.5 m long and cross-section area $10^{-5}m^2$ is stretched 1.5mm by a force of 100N in the elastic region. Calculate (i) the strain (ii) Young's modulus (iii) the energy stored in the wire.

Given Data : $l = 2.5m$, $A = 10^{-5}\ m^2$, $\Delta l = 1.5\ mm = 1.5*10^{-3}$ m, F = 100 N, Strain = ? Y = ? E = ?

$$\text{Strain} = \frac{\Delta l}{l} = \frac{1.5*10^{-3}}{2.5} = 6*10^{-4} \qquad Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{strain} = \frac{100/10^{-5}}{6*10^{-4}} = 1.66*10^{10}\,Nm^{-2}$$

$$Energy = E = \frac{1}{2}\left[\frac{YA(\Delta l)^2}{l}\right] = \frac{1}{2}\left[\frac{1.66*10^{10}*10^{-5}(1.5*10^{-3})^2}{2.5}\right] = 7.5*10^{-2}\,J$$

17.4: What stress would cause a wire to increase in length by 0.01% if the Young's modulus of the wire is $12\times10^{10}\,Pa$. What force would produce this stress if the diameter of the wire is 0.56mm?

$$\text{Given Data : \%elongation} = \text{strain} = 0.01\% = 0.01/100 = 10^{-4},\ Y = 12*10^{10}\,\text{Pa},\ d = 0.56\text{mm}$$

$$r = d/2 = 0.56/2 = 0.28\text{ mm} = 0.28*10^{-3}\text{ m},\ F = ?\ \text{ As Stress} = F/A \text{ then } F = \text{Stress} * \text{Area} - - - (1)$$

$$Y = \frac{\text{stress}}{\text{strain}} \Rightarrow \text{Stress} = Y*\text{strain} = 12*10^{10}*10^{-4} = 12*10^{6}\,\text{Pa} \quad \text{putting in eq (1)}$$

$$F = \text{Stress}*\text{Area} = 12*10^{6}*\pi r^{2} = 12*10^{6}*3.14(0.28*10^{-3})^{2} = 2.95\text{N}$$

17.5: The length of a steel wire is 1.0m and its cross-sectional area is $0.03\times10^{-4}\,m^{2}$. Calculate the work done in stretching the wire when a force of 100N is applied within the elastic region. Young's modulus of steel is $3.0\times10^{11}\,Nm^{-2}$.

$$\text{Given Data : } l = 1\text{ m},\ A = 0.03*10^{-4}\text{ m}^{2},\ F = 100\text{ N},\ Y = 3*10^{11}\text{ Nm}^{-2},\ \text{work } W = ?$$

$$W = \frac{1}{2}F*\Delta l - -(1)$$

$$\text{To find } \Delta l \quad Y = \frac{F/A}{\Delta l/l} \Rightarrow \Delta l = \frac{F*l}{A*Y} = \frac{100*1}{0.03*10^{-4}*3*10^{11}} = 1.1*10^{-4}\,m, \text{ putting in (1)}$$

$$W = \frac{1}{2}F*\Delta l = \frac{1}{2}100*1.1*10^{-4} = 5.55*10^{-3}\,J$$