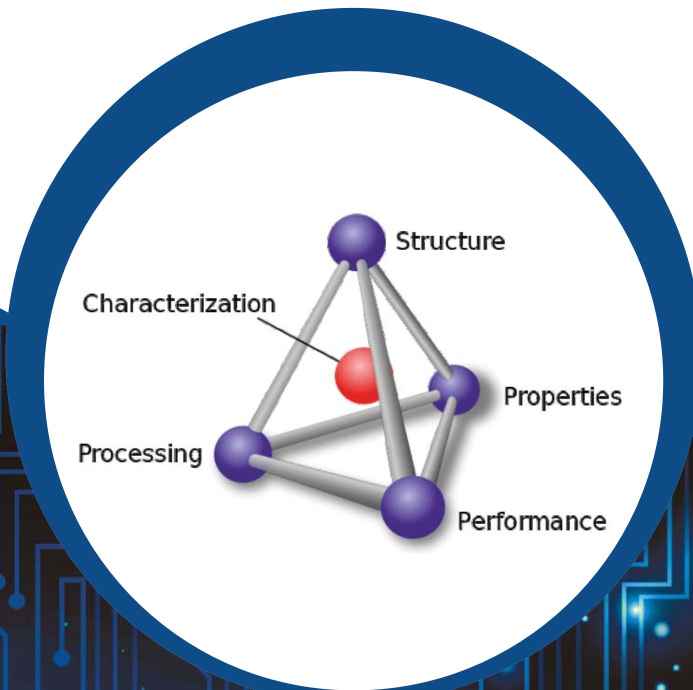
ACE

ESE | GATE | PSUs

ELECTRONICS & TELECOMMUNICATION ENGINEERING

MATERIALS SCIENCE

Volume-I & II: Study Material with Class Room and Self Practice Questions (Workbook)



Chapter 1 Basics of Solid State Physics Crystallography
(Solutions for Text Book Practice Questions)

Objective Practice Solutions

Level-1

01. Ans: (d)
Sol: Vander walls crystal is chemically highly inactive atoms are Inert gas atoms.

02. Ans: (b)
Sol: Hexagonal crystal ⇒ $a = b \neq c$; $\alpha = \beta = 90°$, $\gamma = 120°$

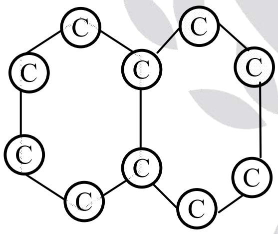
Rhombohedral crystal ⇒ $a = b = c$, $\alpha = \beta = \gamma \neq 90°$

Triclinic crystal ⇒ $a \neq b \neq c$; $\alpha \neq \beta \neq \gamma \neq 90°$

Monoclinic crystal ⇒ $a \neq b \neq c$; $\alpha = \beta = 90° \neq \gamma$

03. Ans: (c)
Sol: GaAs crystallize in Zinc Sulphide form.

04. Ans: (a)
Sol: **Graphite:**



1. In Graphite every carbon atom 3 valance electrons shares with 3 other carbon atoms and forms covalent bonds and the 4th valence electron is bonded with other layer of graphite with weak vander waal's bond
2. The graphite has good electrical and thermal conductor due to presence of 4th valence electron.

05. Ans: (b)
Sol: In FCC, every corner of the cubic cell and face of the cubic cell, the atoms are present and packing efficiency is 0.74. If inside of the cubic cell also atom present, then it represent BCC.

06. Ans: (c)
Sol: The intercepts of the plane are $\frac{1}{2}, \frac{1}{2}$, 1 and its reciprocals are (2, 2, 1). Therefore, the miller indices are (221).

07. Ans: (d)
Sol: Diamond has a diamond cubic structure with atomic packing factor (or) packing density is 0.34. It is the lowest packing density material because in diamond, carbon atoms have low mass number, and hence a smaller radius. small atoms cannot be packed closely.

08. Ans: (b)
Sol: Find Reciprocals of the intercepts of the plane. Miller indices obtained after taking LCM.

Example: For Fig.1, intercepts are 1,α,α. Their reciprocals are 1, 0, 0. Hence Miller Indices (100). Similarly, for the other planes, (200) (100) (111).

09. Ans: (a)
Sol: FCC with two atoms basis of (0 0 0) and a (i + j + k)/4.

10. Ans: (c)
Sol: In FCC structure

$$R = \frac{a\sqrt{2}}{4} \Rightarrow a = \frac{4R}{\sqrt{2}}$$

Volume = a^3

$$a^3 = \left(\frac{4R}{\sqrt{2}}\right)^3$$

$$\Rightarrow \frac{4\times4\times4\times R^3}{\sqrt{2}\times\sqrt{2}\times\sqrt{2}} = 16\sqrt{2}\,R^3$$

11. Ans: (a)

Sol: Co-ordination numbers: It is equal to the number of nearest neighbour to an atom and number of atom touching it for simple cubic co-ordination number: 6
BCC co-ordination number: 8
FCC co-ordination number: 12

12. Ans: (a)

Sol: BCC structure
APF = 0.68
Free volume perunit cell: $4R = \sqrt{3}\,a$

$$a = \frac{4R}{\sqrt{3}} = 0.2886\,\text{nm}$$

$= a^3 \times (1 - \text{APF})$
$= (0.2886)^3 \times (1 - 0.68)$
$= 7.69 \times 10^{-3}$ nm

13. Ans: (d)

14. Ans: (d)

Sol: The cubic cell, a line is projected from origin taken at one of the cube corner point $\left(\frac{1}{2}, 1, 0\right)$
The miller direction is [1 2 0]

15. Ans: (a)

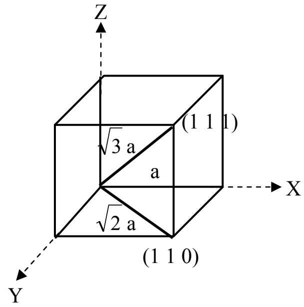
Sol: a, b, c a set of parallel planes
Intercepts are 3a, 4b
Z axis parallel to X, Y $\quad \therefore$ Z = 0
Reciprocal = $\frac{1}{3}, \frac{1}{4}, 0$
= (4, 3, 0)

16. Ans: (a)

Sol: Metallic iron changes from BCC to FCC at 910°C with increases in the atomic radius of iron. Then volume decreases or density increases.

17. Ans: (a)

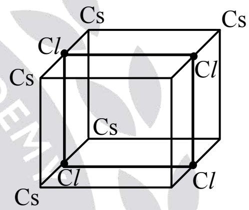
Sol:



The simple cubic crystal is = $\frac{\sqrt{2}\,a}{\sqrt{3}\,a} = \sqrt{\frac{2}{3}}$

18. Ans: (c)

Sol: CsCl structure



CsCl unit cell is $\left(\frac{1}{2}, \frac{1}{2}, \frac{1}{2}\right)$

19. Ans: (b)

Sol: $x \rightarrow a = 1$
$y \rightarrow b = 2$
$z = c = \infty$
intersect the cubic crystal is $\frac{1}{1}, \frac{1}{2}, \frac{1}{\infty}$
= (2, 1, 0)

20. Ans: (c)

Sol: The NET number of sodium cations per unit cell is FOUR, and the NET number of chloride anions per unit cell is also FOUR, so Z (the multiple of the simplest/empirical formula present in the cell) is 4. The 4 : 4 or 1 : 1 ratio of Na : Cl ions present in the unit cell is responsible for the chemical formula of NaCl. Recognize that no independent NaCl entity is present in the unit cell.

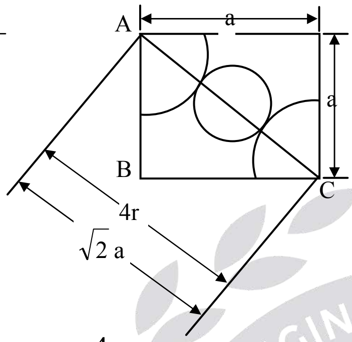
Level-2

01. Ans: (b)

Sol: Atomic packing fraction in FCC

$$P.F = \frac{\text{total volume of atoms in a unit cell}}{\text{volume of unit cell}}$$

$$P.F = \frac{n.\frac{4}{3}\pi r^3}{a^3}$$



FCC: n = 4 and $a = \frac{4r}{\sqrt{2}}$

($\because$ considering the Δ ABC)

$$p.f = \frac{4.\frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3}$$

$= 0.74$

02. Ans: (c)

Sol: Crystal System: Orthorhombic

Lattice parameters: $a \neq b \neq c$,

$\alpha = \beta = \gamma = 90^o$

Possible Bravais lattices : P, I, C, F

Examples : KNO_3, $BaSO_4$, $PbCO_3$

03. Ans: (d)

Sol: Pure ionic solids are excellent insulators at low temperatures due to lack of free electrons; but, as 'T' increases, their ionic conductivity increases.

04. Ans: (b)

Sol: 'Cu' crystallizes in FCC structure.

05. Ans: (d)

Sol: GaAs crystallize in Zinc Sulphide form.

06. Ans: (b)

Sol: Volume of unit cell = a^3 ; No. of atoms per unit cell = 2

Radius of atom $= \frac{a\sqrt{3}}{4}$

Packing fraction = Volume occupied by atoms / volume of the unit cell

$$= \frac{2 \times \frac{4}{3}\pi\left(\frac{a\sqrt{3}}{4}\right)^3}{a^3} = \frac{\sqrt{3}\,\pi}{8}$$

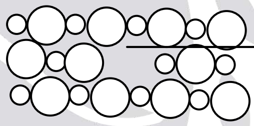
07. Ans: (c)

Sol: Ionic Bond: Losing or gaining of electrons

Covalent Bond: Sharing of electrons

08. Ans: (b)

Sol: Schottky defects: These defects are formed by mixing of cation and anion form the Lattice structure.



09. Ans: (c)

Sol: Whenever X-rays are reflected by a set of parallel planes X-ray diffraction spectrum is produced. Which consists of series of maxima and minima intensity. The crystals are having the structured parallel plane. Hence crystal exhibits uniform X-ray diffraction pattern.

10. Ans: (a)

Sol: Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

11. Ans: (b)

Sol: **Reason**: The no. of atoms per unit cell in BCC Crystal = 2

The number of atoms per unit cell in FCC crystal = 4. So, the difference is 4 – 2 = 2

12. Ans: (c)

Sol: The presence of dislocations makes a crystal mechanically weak. Because of the easy movement of dislocations. The strength of material can be increased by removing all dislocations and making the material a perfect crystal. This is difficult to achieve except in very small hair like crystals (whiskers).

13. Ans: (c)

Sol: In Bravais lattices we have one hexagonal primitive lattices.

14. Ans: (c)

Sol: Nacl unit cell contains 4 Na^+, 4 Cl^- ions.

15. Ans: (a)

Sol: Number of atoms of A from corners of unit cell = 8/8 = 1.
Number of atoms of B from corners of unit cell = 8/8 = 1.
$A : B = 1 : 1 \Rightarrow A_1B_1$

16. Ans: (d)

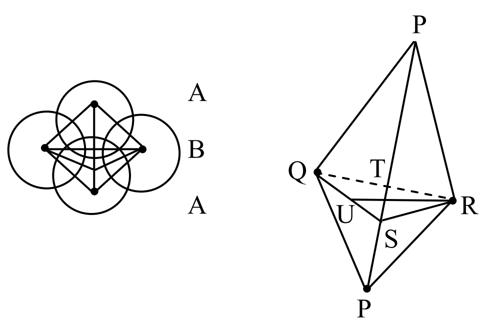
Sol: These are only fourteen independent ways of arrangement points in a three dimensional space lattice is said to be a bravais lattice. These 14 bravais lattice belong to seven crystal and seven multiple crystal system.

17. Ans: (d)

Sol: For ideal hexagonal crystal structure is

$$\frac{c}{a} = 1.633$$

(or)



In HCP arrangement the layers are stacked in ABA as shown in figure. The point Q, R and S represent the centers of atoms on plane B and P is the centre of atoms in plan A just above and below the plane B. Joining the points Q, R & S to P results in two tetrahedral with common base.

a = QR = RS = SQ & c = 2PT

$$\frac{c}{a} = \frac{2PT}{RS}$$

$$RU = \sqrt{RS^2 - SU^2} = \sqrt{a^2 - \frac{a^2}{4}}$$

$$RT = \frac{2}{3}RU = \frac{2}{3}\sqrt{3}\ \frac{9}{2} = \frac{9}{\sqrt{3}}$$

$$PT = \sqrt{PR^2 - RT^2}$$

$$= \sqrt{a^2 - \frac{a^2}{3}} = \frac{a.\sqrt{3}}{\sqrt{3}}$$

$$\frac{c}{a} = \frac{2.PT}{RS}$$

$$\frac{c}{a} = \frac{2\frac{a\sqrt{2}}{\sqrt{3}}}{a} \Rightarrow \frac{c}{a} = 1.633$$

18. Ans: (a)

Sol: Zinc sulphide (ZnS) is the prototype II-VI semiconductor.
Its cubic form (β - ZnS), which occurs naturally as a mineral has given the name zincblende to the crystal structure also called sphalerite.

19. Ans: (c)

Sol: A metallic bond results from the electrostatic attraction between the negative free electron gas and positive ion cores.

20. Ans: (c)

Sol: Thermal conductivity of material is dependent molecular vibrations. In case of non metals there are no free electrons so, only the molecular vibration are responsible for conduction of heat and hence for non metals the conductivity increase with increase in temperature.

21. Ans: (b)

Sol: The defects occurs due the requirement of thermodynamic equilibrium vacancies.

22. Ans: (b)

Sol: MgO → ionic bonding
SiC → covalent bonding
Solid NH_3 → Hydrogen bonding
Solic CH_4 → Vander waals bonding.

23. Ans: (b)

Sol: Given data spacing (1, 1, 1)

Inter planner distance $\lambda = \dfrac{a}{\sqrt{h^2+k^2+\ell^2}}$

$$\frac{a}{\sqrt{1^2+1^2+1^2}} = \frac{a}{\sqrt{3}}$$

$4R = \sqrt{2}\,a$

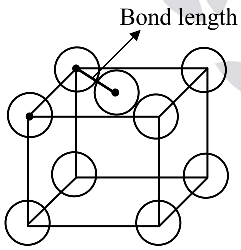
$$a = \frac{4R}{\sqrt{2}} \Rightarrow 0.362$$

$$\lambda = \frac{0.362}{\sqrt{3}}$$

= 0.209 nm = 2A° (Note: 1A° = 0.1 nm)

24. Ans: (a)

Sol:



FCC lattice is $4r = \sqrt{2}\,a$

$2(2r) = \sqrt{2}\,a$

$2(D) = \sqrt{2}\,a$

$$D = \frac{\sqrt{2}\,a}{2} \Rightarrow D = \frac{a}{\sqrt{2}}$$

25. Ans: (d)

Sol: H_2O is a covalent bond/ hydrogen bond.

26. Ans: (b)

Sol: Sodium chloride (Nacl) has a cubic unit cell, it is best thought of as a face-centred cubic (FCC) array of an ions with an inter penetrating FCC cation lattice (or) vice-versa.

27. Ans: (d)

Sol: The unit cell of zinc blende structure has a four zinc ions and four sulphur ions.

28. Ans: (a)

Sol: Ionic solids are soluble in polar solvents like water and liquid ammonia.
Ionic solids have high melting and boiling points, pure and dry ionic solids are good insulators because all the electrons are tightly bound.

29. Ans: (d)

Sol: The infrared spectrum of the 1:1 complex in the vapour phase between water and hydrogen fluoride (HF) has been observed for the first time.

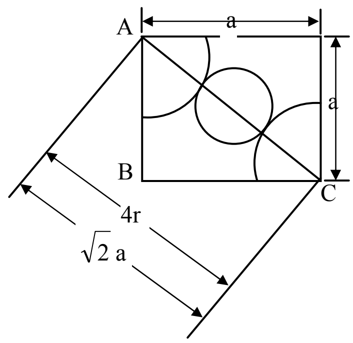
30. Ans: (c)

31. Ans: (a)

Sol: Atomic packing fraction in FCC

$$P.F = \frac{\text{total volume of atoms in a unit cell}}{\text{volume of unit cell}}$$

$$P.F = \frac{n.\frac{4}{3}\pi r^3}{a^3}$$



FCC: n = 4 and $a = \frac{4r}{\sqrt{2}}$

($\because$ considering the Δ ABC)

$$p.f = \frac{4.\frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3}$$

= 0.74

32. Ans: (d)

Sol: Metals do not have the property of transparent to electromagnetic radiation.

33. Ans: (c)

Sol: Copper, silver and gold the covalent bond which are filled in the ground state are treated in E-B model as transition elements in order to account for their bond strengths and FCC lattices. A larger position of bonding is attributed to their d states. These considered to have $d^{9.3}$ $SP^{0.7}$ electron configuration with 2.4 bonding electrons per ion.

34. Ans: (b)

Sol: Covalent substances are soluble in some non polar solvents like benzene and carbon disulphide. The melting and boiling points of covalent solids are usually low as compared to those of ionic compounds.

Some covalent solids are Conductors (lead, tin) some are semiconductors (Si, Ge) and some are insulators (Carbon in diamond form). Covalent compounds can exist as solids, liquids and gases.

35. Ans: (a)

Sol: Number of atoms per unit cell in diamond structure = 8.

36. Ans: (b)

Sol: The amorphous substances posses is

1. No specific arrangement of atoms.
2. May have short range order.
3. Bond length & strength are unequal.

37. Ans: (b)

Sol: Copper crystal belongs to a closed packed FCC structure.

38. Ans: (d)

Sol: Calcium carbonate particle has a rhombohedral basic structure-even with every fine grinding rupture occurs in the grating palne (or) axis of symmetry of the natural crystal structure.

39. Ans: (c)

Sol: Cesium chloride, is the inorganic compound with the formula CsCl. This colorless solid is an important source of cesium ions in a variety of niche applications. Its crystal structure forms a major structural type where each cesium ion is coordinated by 8 chlorine ions.

Conventional Practice Solutions

01. Ans: 5.425 gm/cc

Sol: Given the structure of Ge is diamond cubic its lattice parameter is 5.62 A. Its atomic weight is 72.5 calculate its density

The density d is given, $d = \frac{p\mu}{Na^3}$

p = number of atoms per unit cell = 8

μ = Atomic weight of Ge = 72.5

N = Avogadro's number = 6.023×10^{23} per gram mole

a = lattice parameter = 5.62×10^{-10} m

$$d = \frac{8\times 72.5}{6.023\times 10^{23}\times(5.62\times 10^{-10})^3}$$

d = 5.425 gm/cc

02. Ans: 8.82 gm/cc, 0.53 A°

Sol: **(a)** Given crystal structure of copper is FCC. Its atomic radius 1.28A^o. atomic weight of copper is 63 the density is given by

$$d = \frac{p\mu}{Na^3}$$

$p = 4$, $\mu = 63$, $N = 6.023\times10^{23}$, $a = 2\sqrt{2}r$

Hence,

$$d = \frac{4\times 63}{6.023\times 10^{23}\times 16\sqrt{2}\times(1.28\times 10^{-10})^3}$$

d = 8.82 gm/cc.

(b) Let R be the radius of the atom that can be fitted into the octahedral void space. Then

A = 2(r + R); r = 1.28 A°

$$\Rightarrow R = \frac{a}{2} - r = \sqrt{2}r - r = \left(\sqrt{2}-1\right)r$$

$$= 0.53A^o$$

03. Ans: 9.09 × 10^{28}

Sol: Given atomic weight of Ni = 58.7

Density of Ni   d = 8.9 gm/cc

Lattice parameter a = 3.53A^o

Structure is cubic

Using the formula $a = \left(\frac{p\mu}{Nd}\right)^{1/3}$

We have for the number of atoms/unit cell

$$p = \frac{Nda^3}{N_i}$$

$$= \frac{6.023\times10^{23}\times 8.9\times 3.53^3\times 10^{-24}}{58.7}$$

p = 4.016

The structure is FCC.

Number f atoms per

$$m^3 = \frac{4}{a^3} = \frac{4}{3.53^3\times 10^{-30}} = 9.09\times 10^{28}$$

04. Ans: 132.44

Sol: Given cesium has BCC structure. Its lattice parameter is a = 6.14 A^o. It has a density 1.9 gm/cc

Using the formula $d = \frac{p\mu}{Na^3}$

The atomic weight $\mu = \frac{Na^3 d}{p}$

$$= \frac{6.023\times10^{23}\times 6.14^3\times 10^{-24}\times 1.9}{2}$$

μ = 132.44

05. Ans: 3.6 A^o

Sol: Given atomic weight of copper = 63 and density = 8.96 gm/cc its structure FCC. The lattice parameter is given by

$$a = \left(\frac{p\mu}{Nd}\right)^{1/3}$$

$$= \left(\frac{4\times 63}{6.023\times 10^{23}\times 8.96}\right)^{1/3}$$

= 3.6 A^o

Chapter 2 Conducting Materials

Objective Practice Solutions

Level-1

01. Ans: (b)

Sol: Any impurities will act as scattering centers and resistivity increases (or) conductivity decreases.

02. Ans: (c)

Sol: Hall voltage V_H = ?

Thin copper plates $t = 0.1 \times 10^{-3}$ m

$B_2 = 1$ Wb/m^2

$R_H = 7.4 \times 10^{-11}$ m^3/c

I = 100 A

$V_H t = B_Z R_H I$

$V_H t = B_Z R_H I$

$$V_H = \frac{B_Z R_H I}{t}$$

$$V_H = \frac{1 \times 7.4 \times 10^{-11} \times 100}{0.1 \times 10^{-3}}$$

$V_H = 7.4 \times 10^{-5} = 74 \times 10^{-6} = 74\ \mu F$

(or)

$R_H BI$

$$V_H = \frac{R_H BI}{t}$$

Hall voltage $V_H = 74\ \mu V$

03. Ans: (a)

Sol: The electrical conductivity of solid solution is lesser 10^{14} Hz the pure metals. It is decreases with increase in alloy content because of creating crystallographic imperfection by adding alloying elements and due to that regular structure is disturbed so statement I and statement II are correct and statement II is correct explanation for statement –I.

04. Ans: (a)

Sol: In hard drawn copper, cold working will increases mechanical distortions (dislocations) which act as electron scattering centers and resistivity will be more. In annealing, lattice defects get reduced and resistivity will be less.

05. Ans: (b)

Sol: Both the sentences are individually correct but statement (II) is not correct explanation for statement (I).

06. Ans: (a)

Sol: Carbon (Diamond) → Insulation

Silicon → Semiconductor

Tin & Lead→ Conductor

07. Ans: (a)

Sol: According to classical free electron theory, the electrons in a metal are subjected constant potential.

08. Ans: (b)

Sol: Lead is a good conducting, low strength material. It possess good malleability and ductile properties. It is least affected by sea water.

If forms alloy with many other metals (Ex:- soldering alloy of pb + sn) and it is also used in cable sheath

09. Ans: (a)

Sol: The electrical resistivity of silver is lower then that copper. So the statement II is incorrect.

The electrical conductivity of metal decreases by adding impurities to the host material, even though by adding high conductivity (silver) atoms added to copper as an impurity, it's overall conductivity decreases then pure host material

10. Ans: (a)

Sol: A good conductor of electricity is as follows:

1. It's conductivity decreases with increasing temperature
   $\rho_{t2} = \rho_{t1}[1 + \alpha(T_2 - T_1)]$
2. Number of free electrons is around 10^{28} per m^3
3. It's conductivity decreases with addition of impurities
4. There also possess good thermal conductivity

11. Ans: (c)

Sol: If the temperature of metal increases, the lattice vibration in the crystal structure increases. Hence collision frequency increases and relaxation time decreases. Due to that resistivity of metal increases

12. Ans: (a)

Sol: Given data,
Temperature co-efficient of resistance of a wire = 0.0008/°C
The resistance of the wire = 8Ω at 0°C
Then 100°C
r = ?

$\rho(100) = \rho(0)\ [1 + 0.0008 \times 100]$
$= 8.64$ Ohm

13. Ans: (b)

Sol: Because increasing the impurity content destroys the periodicity of the lattice, which decreases the conductivity.

14. Ans: (b)

Sol: According to Weidemann - Franz law

$\frac{k}{\sigma} \propto T \ ; \ \frac{k}{\sigma} = LT,$

where L- Lorentz number.

15. Ans: (a)

Sol: We have $V_d = \mu E$ and $\mu = \frac{Q_e E T}{m_e}$

16. Ans: (a)

Sol: In a Hall effect except the applied magnetic field is doubled while the ohmic current density is left unchanged. As a result, the Hall voltage is doubles.

17. Ans: (a)

Sol: Given data,
$n_i = 2.37 \times 10^{19}\ m^3$
$\mu_e = 0.38\ m^2V^{-1}S^{-1}$
$\mu_n = 0.18\ m^2V^{-1}S^{-1}$

Conductivity $\sigma = n_i e(\mu_e + \mu_n)$
$= 2.37 \times 10^{19} \times 1.6 \times 10^{-19}(0.38 + 0.18)$
$= 2.1235\ \Omega^{-1}m^{-1}$

18. Ans: (d)

Sol: Hall effect:
(i) Sign and concentration of carriers
(ii) Mobility and drift velocity of carriers.
(iii) Conductivity and type of semi conductors.

19. Ans: (d)

Sol: When a n-type semiconductor sample is used in this experiment, both electron and holes get deflected towards the upper surface of the block. But as the electron concentration is more than that of holes, the potential of the upper surface is negative with respect to the lower surface. And the Hall potential difference is negative. Thus the Hall coefficient R_H is negative for n-type semiconductors.

20. Ans: (c)

Sol: When no current is passed through a conductor, the average velocity of a free electron over a large period of a time is zero. The average of the velocities of the free electrons at an instant is zero.

Level-2

01. Ans: (a)
Sol: An electrical balanced atom has to protons and 2 electrons in the outermost shell. An insulator material made of such atom with $Z = z_0$ is zinc.

02. Ans: (a)
Sol: Manganin alloy has the lowest temperature coefficient of resistance: 0.0000002 Ω /°C.

03. Ans: (d)
Sol:

Model	Particle properties	Examples
1.Maxwell- Boltzmann	Distinguishable unlimited particles per quantum state	Ideal gas, Molecules
2.Bose Einstein	Indistinguishable unlimited particles per quantum state	Photon, phonon
3.Fermi Dirac	Indistinguishable, identical one particle Per quantum state (Pauli exclusion principle)	Electron, protons

04. Ans: (c)
Sol: The Fermi energy is defined as the energy of the top most filled level in the ground state of the N electron system Fermi energy

$$(E_F) = \frac{h^2}{2m}\left(\frac{3\pi^2 N}{L^3}\right)^{2/3}$$

$$E_F \alpha N^{2/3}$$

05. Ans: (c)
Sol: Group III elements (trivalent impurity) when added to an element semiconductor results in formation of p-type semiconductor.

Group III elements: Boron, Aluminium, Gallium, and Indium

06. Ans: (c)
Sol The resistivity of a metal is a function of temperature because with increasing temperature, the lattice vibrations increases and due to that collision of electrons takes place.

07. Ans: (b)
Sol: Based on kinetic theory of gases, the electron have constant velocity, and velocity of electrons is

$$V_{rms} = \sqrt{\frac{3k_pT}{m}}$$

08. Ans: (c)
Sol: Germanium is a semi conductor

09. Ans: (d)
Sol: Manganin has almost zero temperature variation of resistance.

10. Ans: (b)
Sol: According to Matthiersen's rule $\rho = \rho_r + \rho_T$; ρ_r depends on the structural defects of the material and imperfections. ρ_T is temperature dependent.

11. Ans: (a)
Sol: Given data,
A conductor carrier a current = 4 A
$e = 1.6 \times 10^{19}$
B = ?

$$I^\rho = \frac{q}{t} = \frac{ne}{t}$$

Therefore, $n = \frac{I^\rho \times t}{e} = 2.5 \times 10^{19}$

12. Ans: (d)
Sol: Addition of any impurity increases the resistivity of host material

13. Ans: (c)

Sol: 1. Aluminium is used in Telephone cords and trolley wires.
2. Phosphor Bronze is used in current carrying springs
3. Carbon is used in commutator brush
4. Nichrome is used in heating elements

14. Ans: (c)

Sol: Because impurity atoms act as scattering centers this increases the resistivity.

15. Ans: (a)

Sol: Two samples of Ge and silver are heated from 0 K to 300 K. Then the conductivity of Ge increases and silver decreases.

16. Ans: (c)

Sol: Energy bands occur in solids where the discreet energy levels of the individual atoms merge into bands which contain a large number of closely spaced energy levels.In this section, we first discuss the crystal structure of common semiconductors to illustrate the fact that most semiconductors have an ordered structure in which atoms are placed in a periodic lattice. We then consider the Kronig-Penney model. This one dimensional model illustrates how a periodic potential yields a set of energy bands and energy band gaps.

17. Ans: (b)

Sol: A metal consists of electrons which are free to move about in the crystal like molecules of a gas in a container. Mutual repulsion between electrons is ignored and h ence potential energy is taken as zero.

18. Ans: (c)

Sol: Fermi energy of metal (E_F) = 1.4 eV

K = 1.38×10^{-23} J/K

e = 1.6×10^{-19}

Fermi temperature (T_F) = $\frac{E_F}{k}$

$$T_F = \frac{1.4\times1.6\times10^{-19}}{1.38\times10^{-23}} = 1.6 \times 10^4 \text{ K}$$

19. Ans: (b)

Sol: Given data,

$n = 6 \times 10^{28}$, $e = 1.6 \times 10^{-19}$, $\tau = 1.4 \times 10^{-14}$

conductivity $\sigma = \frac{ne^2\tau}{m}$

$$= \frac{6\times10^{28}\times\left(1.6\times10^{-19}\right)^2\times1.4\times10^{-14}}{9.1\times10^{-31}}$$

$= 2.36 \times 10^7$

20. Ans: (c)

Sol: Given data,

$n = 5.8 \times 10^{28}$, $e = 1.6\times10^{-19}$, $m = 9.1\times10^{-31}$

$\rho = 1.54 \times 10^{-8}$

$$\rho = \frac{ne^2\tau}{m}$$

$$\frac{1}{\rho} = \frac{ne^2\tau}{m}$$

$$\tau = \frac{m}{\rho ne^2} = \frac{9.1\times10^{-31}}{1.54\times10^{-8}\times5.8\times10^{28}\times\left(1.6\times10^{-19}\right)^2}$$

$= 3.979 \times 10^{-14}$ s

21. Ans: (b)

Sol: Given data,

$R_H = 3.66 \times 10^{-4}$

$e = 9 \times 10^3$

$$n_h = \frac{1}{R_H e}$$

$$n_h = \frac{1}{3.66\times10^{-4}\times1.6\times10^{-19}}$$

$n_h = 1.7076 \times 10^{22}$

Mobility of carries $\mu_n = \frac{1}{\rho ne}$

$$= \frac{1}{9\times10^{-3}\times1.707\times10^{22}\times1.6\times10^{-19}}$$

$= 0.41$ m^2/V-s

22. Ans: (a)

Sol: Given data,

Length = 10 mm, breadth = 10 mm,

Thickness = 1 mm,

$R_H = 3.66 \times 10^{-4}$

$B = 0.5 \text{ Wb/m}^2$

Hall voltage $V_H = \frac{BIR_H}{W}$

$$= \frac{0.5\times10^{-2}\times3.66\times10^{-4}}{10\times10^{-3}}$$

= 18 mV

23. Ans: (b)

Sol: The Fermi energy is defined as the energy of the top most filled level in the ground state of the N electron system Fermi energy

$$(E_F) = \frac{h^2}{2m}\left(\frac{3\pi^2 N}{L^3}\right)^{2/3}$$

$E_F \alpha N^{2/3}$

$N \propto E_F^{3/2}$

24. Ans: (c)

Sol: As the temperature of a metallic resistor is increased, the product of its resistivity and conductivity is increases.

25. Ans: (a)

Sol: A resistor of resistance R is connected to an ideal battery. If the value of R is decreased, the power dissipated in the resistor will increase.

26. Ans: (d)

Sol: When a resistor connected to a battery is heated due to the current do not change in number of free electrons.

Conventional Practice Solutions

01. Ans: 5.74×10^{22}, 7.4×10^{-3} m²/V-s

Sol: **(i)** Given density of silver as 10.5 gm/cc. It height = 108. To calculate the number of electrons per cc.

108gm of silver contains Avagadro number of atoms. Since the valance of silver is one each atoms gives one free electron.

The number of free electron per cc

$$= \frac{6.023\times10^{23}}{108}\times10.5 = 5.74\times10^{22}$$

(ii) The conductivity and mobility are related as $\sigma = ne\mu$

Given $\sigma = 6.8\times10^7$ mho/m

$n = 5.74\times10^{28}$ /m³

$e = 1.6\times10^{-19}$

$$\mu = \frac{\sigma}{ne} = \frac{6.8\times10^7}{5.74\times10^{28}\times1.6\times10^{-19}}$$

$= 7.4\times10^{-3}$ m²/V-s

02. Ans: 2.37 m/s

Sol: The conduction electron in copper is acted by an electron field E = 5V/cm = 500V/cm

It produces an acceleration of $a = \frac{eE}{m}$

The increase in velocity $v = \left(\frac{eE}{m}\right)\tau$

Given $\tau = 2.7\times10^{-14}$ sec

Hence, $v = \frac{1.6\times10^{-19}\times500}{9.1\times10^{-31}}\times2.7\times10^{-14}$

= 2.37 m/s

03. Ans: 0.04 m²/V-s, 1.708×10^{22} per m³

Sol: Given Hall coefficient R_H

$$= 3.66\times10^{-4} \text{ m}^3/\text{c} = \frac{1}{ne}$$

Hence charge carrier density

$$n = \frac{1}{R_H.e}$$

$$n = \frac{1}{3.66\times10^{-4}\times1.6\times10^{-19}}$$
$= 1.708\times10^{22}$ per m^3

The resistivity $\rho = \frac{1}{ne\mu} = \frac{R_H}{\mu}$

Hence,

$$\mu = \frac{R_H}{\rho} = \frac{3.66\times10^{-4}}{8.93\times10^{-3}} = 0.04m^2/V-s$$

04. Ans: 8.93×10^{19} per m^3

Sol: Using the expression $\rho = \frac{1}{ne\mu}$ we can calculate the electron concentration n as

$$n = \frac{1}{pe\mu} = \frac{1}{0.2\times1.6\times10^{-19}\times0.35}$$
$= 8.93\times10^{19}$ per m^3

05. Ans: 1.44 × 10^{16} m^3

Sol: Given the intrinsic concentration n_i

$= 2.4\times10^{19}$ /m^3

Concentration of Ge atoms in the sample

$= 4\times10^{28}$ /m^3

Doping concentration

= 1 sb atom for every 10^6 Ge atom

Number of electron = 4×10^{22}

one concentration of minority hole concentration is obtained from law of mass action

$$b = \frac{n_i^2}{n} = \frac{(2.4\times10^{19})(2.4\times10^{19})}{4\times10^{22}}$$
$= 1.44\times10^{16}$ / m^3

Chapter 3 Magnetic Materials

Objective Practice Solutions

Level-1

01. Ans: (a)

Sol: A special class of ferrites called 'ferrox cubes' are used as computer memory elements.

02. Ans: (a)

Sol:
- Hysteresis is characteristic property of ferromagnetic materials.
- Field applied in order to destroy remenant magnetization is called coercive field.

03. Ans: (c)

Sol: A ferromagnetism property of a group of atoms or molecules in a solid crystal (or) lattice. All ferromagnetic substances have unpaired electron spins that are strongly entwined by a quantum mechanical force exchange interaction large groups of atoms in ferromagnetic substance form magnetic domains in which electron spins become locked together in alignment.

04. Ans: (c)

Sol: Hard magnetic materials are used for making permanent magnets because they have wide and large hysteresis loop, high retentivity and coercivity

05. Ans: (d)

Sol: According to curie law,

$\chi \propto \frac{1}{T} \Rightarrow \chi = \frac{C}{T}$ Where, C: curie constant

06. Ans: (b)

Sol: Given data,

A bar magnetic made of steel has magnetic moment 2.5 Am^2

Mass = 6.6×10^3 kg,

Density = 7.9×10^3,

Intensity of magnetization = ?

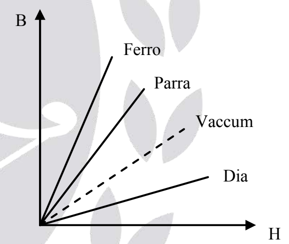
The volume of the bar magnet is

$$V = \frac{6.6 \times 10^{-3}\ \text{kg}}{7.9 \times 10^3\ \text{kg/m}^3} = 8.3 \times 10^{-7}\ \text{m}^3$$

$$\therefore\ I = \frac{m}{V} = \frac{2.5\ \text{A} - \text{m}^2}{8.3 \times 10^{-7}\ \text{m}^3} = 3 \times 10^6\ \text{A/m}$$

07. Ans: (c)

Sol: The graph between magnetic flux density (B) and applied field (H) for different magnetic material is



08. Ans: (c)

Sol: Based on weiss-Domain Theory, the magnetic

1. Expand at initial field. If is a reversible process
2. Rotate the dipoles in domains in the direction of fields high magnetic field. It is an irreversible process.

09. Ans: (a)

Sol: Ferrites are useful at very high frequencies because of high permeability & low eddy current losses (or) high resistivity.

10. Ans: (d)

Sol: 1. No eddy current losses ⇒ Ferrimagnetic materials

2. Small hysteresis losses ⇒ Soft magnetic materials

3. Large hysteresis losses ⇒ Hard magnetic materials

11. Ans: (d)

Sol: Permalloy is an example of soft magnetic material.

12. Ans: (b)

Sol: Metallic copper is an example of diamagnetic material.

13. Ans: (d)

Sol: The spontaneous magnetization of a domain in a ferromagnetic crystal is accompanied by an elongation or contraction in the direction of magnetization, called magnetostriction.

14. Ans: (b)

Sol: In Anti-ferromagnetic materials, above a specific Neel temperature the anti parallel arrangement breaks down and the material becomes paramagnetic, temperature dependence of susceptibility, i.e. when

$T > T_N$ (Neel Temperature) $\chi = \dfrac{C}{T+\theta}$

15. Ans: (d)

Sol: Ferrites are metallic oxide ceramic materials insulating in nature so that ferries are much more resistivity than ferromagnetic materials. Electrons in ferrites makes ionic bonds by complete transfer of electrons

16. Ans: (d)

Sol: Superconductors are perfect diamagnetic materials having susceptibility as −1.

Diamagnetic material susceptibility is negative and small.
Paramagnetic material susceptibility is positive and small.
Ferromagnetic material susceptibility is positive and large.

17. Ans: (a)

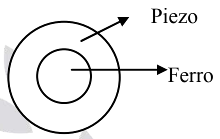
Sol: 1. Ferroelectic material

Eg: $BaTiO_3$, Pb [ZrO_3, TiO_3], KH_2PO_4

2. Piezoelectric material

Eg: Quartz, $BaTiO_3$

Pb [ZrO_3, TiO_3], KH_2PO_4



3. Soft magnetic material

Eg:Perm alloy, superm alloy, pure Iron, Fe-Si alloy

4. Hard magnetic material

Eg: Alnico, Tungsten Steel

18. Ans: (b)

Sol: Sodium is paramagnetic because of unpaired electrons in the outermost orbit.

19. Ans: (d)

Sol: 3d electron spin direction is responsible for magnetic moment. For Cobalt, number of 3d electrons = 7 Spin direction:↑ ↑ ↑ ↑ ↑ ↓ ↓

∴ Magnetic moment = 3 Bohr magnetron.

20. Ans: (a)

Sol: In a transformer, the core should have low coercivity and retentivity. Because high hysteresis loop area implies high hysteresis loss. Hence soft magnetic materials are used in the transformer core. In a transformer, the core should have high permeability to produce high magnetic flux density.

Level-2

01. Ans: (c)

Sol: In permanent magnets every atom behaves like a small dipole (atomic dipoles) and they are all aligned perfectly parallel to each other when heated, temperature increases, thermal agitation increases means atoms (dipolar) are vibrating at high temperatures, due to increased thermal agitation, the dipoles start realigning from their parallel orientation. All these factors causes loss of magnetism.

02. Ans: (b)

Sol: The magnetic field required to destroy residual magnetization is called coercivity field H_c.

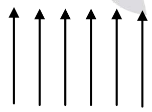
03. Ans: (b)

Sol:

(i) Both Ferro and Ferri, have domain structures

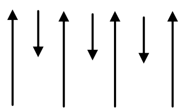
(ii) In both Ferro & Ferri, domain grow in size

(iii) Ferro domains all dipoles are parallel



In Ferri, the dipoles are anti parallel and are of un-equal magnitudes. But still in 'ferri material' positive net magnetic moment can be said to be higher than Ferro, because the effective dipole moment in anti parallel arrangement is greater in magnitude.

Thus Ferri materials have very high permeability and susceptibilities as compared to Ferro.



04. Ans: (b)

Sol: Ideal Core Material

(i) for an ideal core $\mu_r = \infty$ i.e., very high permeability and coercivity $H_c = 0$. such that no hysterisis loss. i.e., its B-H loop should be y-axis.

$\Rightarrow$ Even when there is no current, it can have any B (flux) value.

(ii) Core saturation implies, flux in the core doesn't increase with increasing H which is undesirable.

05. Ans: (a)

Sol: $\mu_r = 1 + \psi_m$

Where ψ_m is the magnetization susceptibility is given by

$\psi_m = \frac{M}{H}$ (or) $M = \psi_m H$

M = Magnetization

(or)

The relative permeability of a medium μ_r the 3 field vectors are related as

$B = \mu_0 (M+H)$; as $B = \mu H$

$\mu H = \mu_0 (M+H)$

$$\frac{\mu}{\mu_0} = \frac{M}{H} + 1$$

$$\mu_r = \frac{M}{H} + 1$$

06. Ans: (c)

Sol: The imaginary part of the complex dielectric constant is a measure of dielectric loss.

07. Ans: (a)

Sol: Ferrites have high resistivity and hence low eddy current loss and high Q-factor, therefore they are suitable for high frequency applications.

08. Ans: (c)

Sol: Diamagnetic materials has a highest reluctance.

09. Ans: (d)

Sol: The plays an important role in the fine recording of audio signals on speed of the motor in magnetic tape recorder.

10. Ans: (a)

Sol: Soft magnetic materials have small retentivity and coercivity. Hence can be magnetized or demagnetized easily in either direction.

11. Ans: (a)

Sol: $B = \mu H$

$= \mu_o \mu_r H$

i. e. $B = \mu_o \mu_r H + \mu_o H - \mu_o H$

$= \mu_o H + \mu_o H (\mu_r - 1)$

$= \mu_o H + \mu_o M$

Where the magnetisation M is equal to H $(\mu_r - 1)$

i.e. $B = \mu_o(H + M)$ ------(1)

The first term on the right side of Eq. (1) is due to external field. The second term is due to the magnetisation.

Thus the magnetic induction (B) in a solid is

$B = \mu_o(H + M)$

Hence $\mu_o = \frac{B}{H+M}$

The relative permeability

$$\mu_r = \frac{\mu}{\mu_o} = \frac{B/H}{B/H+M} = \frac{H+M}{H} = 1 + \frac{M}{H}$$

$\mu_r = 1 + \chi$

12. Ans: (c)

Sol: Soft iron is characterized by the saturation magnetization M_s is large, coercivity H_c and retentivity B_c are small.

13. Ans: (a)

Sol: Diamagnetic susceptibility is very small and negative.

14. Ans: (b)

Sol: It is the ability of material that can change physical dimension by applying magnetic field.

15. Ans: (c)

Sol: Superconductors when cooled below their critical temperature exhibit zero resistivity.

16. Ans: (c)

Sol: Hard magnetic materials are used for making permanent magnets because they have wide and large hysteresis loop, high retentivity and coercivity.

17. Ans: (b)

Sol: The magnetic moments of diamagnetic materials are mainly due to the orbital angular momentum of the electrons. so statement I is correct.

A steady current flowing in the orbit produces a Magnetic fie equivalent to that set up by a dipole perpendicular to the plane of orbit this statement is also correct but not the correct explanation for statement I.

18. Ans: (a)

Sol: Soft magnetic materials are not used in the constructions of permanent magnets, but hard magnetic materials are used. so statement I is correct.

Soft magnetic materials have narrow hysteresis loop, low retentivity and low coercivity and hence these are not used in permanent magnets.

19. Ans: (b)

Sol: If the magnetic susceptibility of a specimen is small and positive, the specimen is a paramagnetic material.

20. Ans: (b)

Sol: Structural formula for ferrite is $MOFe_2O_3$

21. Ans: (c)

Sol: <u>**Magnetostriction**</u>: It is the ability of material that can change physical dimension by applying magnetic field.

22. Ans: (c)

Sol: The atomic thermal motions are not affecting the atomic dipole alignment.

23. Ans: (d)

Sol: Silicon element is added to iron or steel to reduce the hysteresis losses.

24. Ans: (c)

Sol: High frequency transformer cores are generally made from ferrites. These ferries are ceramics with electrically insulating character and their eddy current losses are very low.

25. Ans: (b)

Sol: Alnico is an alloy of Al-Ni-co. It is a hard magnetic material and the hysterias loop area is also large. So there are highest energy per unit of cost or valence material. So statement I is correct

The Alnico alloy is very hard and brittle, therefore they cannot be machined. Statement II is also correct. Statement I explains above magnetic properties and statement II explain above mechanical properties of Alnico

26. Ans: (d)

Sol: All substances except diamagnetic materials exhibit permanent dipole moment.

27. Ans: (b)

Sol: Flux $\phi = B \times A$

$\therefore B = \phi/A = 0.4$ T

28. Ans: (c)

Sol: Curie's law for paramagnetic substances is $\chi \propto \frac{1}{T}$

29. Ans: (b)

Sol: The high permeability magnetic materials domain walls are easily moved. with small applied magnetic field.

30. Ans: (a)

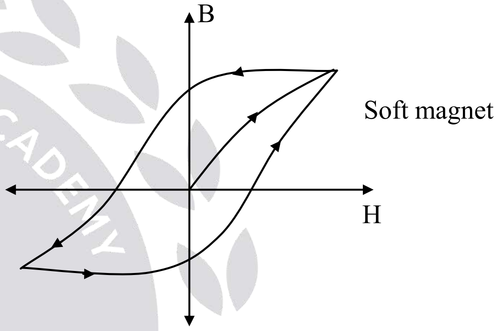
Sol: Soft Iron is a soft magnetic material with narrow and tall hysteresis loop

→ Low coercivity

→ High susceptibility

→ High permeability

→ It conducts electricity also



31. Ans: (d)

Sol: Diamagnetic materials donot have permanent dipoles. They induce dipoles by applying field.

32. Ans: (c)

Sol: Based on weiss- Domain Theory, the magnetic

1. Expand at initial field. If is a reversible process
2. Rotate the dipoles in domains in the direction of fields high magnetic field. It is an irreversible process.

33. Ans: (d)

Sol:
1. Silicon steels are used in power transformer
2. Ferrites are used in High frequency transformers
3. Alnico is used as a permanent magnet

34. Ans: (a)

Sol: To reduce eddy current losses the core of transformer it built up on lamination.

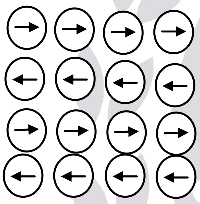
35. Ans: (d)

Sol: soft magnetic materials are not used in the fabrication of permanent magnets but hard magnetic materials are used so assertion is in correct.

Soft magnetic material domain movement is easy, where as hard magnetic material domain movement is difficult.

36. Ans: (d)

Sol: In Antiferro magnetic material, the dipoles are antiparallel with equal magnitudes so their net magnetization is zero



37. Ans: (b)

Sol: The YIG is a good soft magnetic material.

The YAG is a non-magnetic ceramic material

38. Ans: (b)

Sol: 1. Super conductor

$\Rightarrow \chi$ = Negative and very high

2. Ferric chloride (Paramagnet)

$\Rightarrow \chi$ = Positive and small

3. Diamond (Diamagnet)

$\Rightarrow \chi$ = Negative and small

4. Manganese oxide (Anti Ferro magnet)

$\Rightarrow \chi = \dfrac{C}{T+\theta}$ (Neel's Law)

39. Ans: (b)

Sol: In paramagnetic, the susceptibility is largely dependent on temperature. Curie's Law: $\chi = \dfrac{C}{T}$ & χ is positive and very small.

40. Ans: (d)

Sol: At finite temperature magnetic dipoles in a material are randomly oriented giving low magnetization when the magnetic field H is applied, then magnetization.

(i) increases with H

(ii) decreases with temperature for constant H.

41. Ans: (b)

Sol: Ferrites are particularly suited for high frequency applications because of their low eddy current loss.

42. Ans: (a)

Sol: The Susceptibility of diamagnetic materials is independent of temperature.

43. Ans: (a)

Sol: Ferrites are metal oxide ($M_n Fe_2 0_4$) ceramics with high magnetic flux density with minimum eddy current losses and hence they are used in inductances for high frequencies

44. Ans: (b)

Sol: Tall → high saturation magnetization

narrow → low coercive field

45. Ans: (b)

46. Ans: (b)

Sol: The magnetic moment due to the spin of the electron is 1 Bohrmagnetron

$(1\ \mu_B) 1\ \mu_B = \dfrac{eh}{4\pi m} = 9.27\times10^{-24}\ \dfrac{J}{T}$

The effective orbital moment is present only when unpaired electrons are present in p, d, … etc. orbitals. [In S orbital $\mu_1 = 0$]

47. Ans: (a)

Sol: Eddy current loss is minimized using a ferrite core which has large resistance.
Also by using laminated sheets with insulated coatings.

48. Ans: (c)

Sol: The temperature at which a conductor becomes a super conductor is called critical or transition temperature (T_c)

49. Ans: (b)

Sol: The properties of material for the core in a power transformer

1. High permeability
2. High saturation magnetization
3. High susceptibility

50. Ans: (a)

Sol: Ferrites are the modified structure of iron with no carbon. Ferrites and Garnets have high electrical conductivity than that of hard magnetic alloys. This reduces the eddy current losses.

51. Ans: (c)

52. Ans: (c)

Sol: Diamagnetic susceptibility is negative, small and is independent of temperature and field strength.

53. Ans: (d)

Sol:
1. Silicon steels are used in power transformer
2. Ferrites are used in High frequency transformers
3. Alnico is used as a permanent magnet

54. Ans: (c)

Sol: In ferromagnetic materials, the atomic moments are parallel. Ferromagnets become very strongly magnetized in a weak external field and may possess a spontaneous magnetic moment even in zero field.
Ferro magnetism only exists below certain temperature, the Curie temperature T_c, above which the substance becomes paramagnetic. The relative permeability of these materials is very large and positive.

55. Ans: (a)

Sol: Electrical resistivity has to high for ferrites, not for 4% Si-Fe. Which is ferromagnetic material further upon adding 4% Si coercive force and B_{sat} both decreases.

56. Ans: (b)

Sol: For transition elements like Fe, Co, Ni, the ratio of the atomic diameter to 3D orbital diameter is in the range of 1 to 1.5.

57. Ans: (d)

Sol: Structural formula for ferrites is AOB_2O_3 or AB_2O_4.

58. Ans: (c)

Sol: A. Ni-Zn Ferrite
$\rightarrow$ Audio & TV transformers

B. Co-Sn alloy
$\rightarrow$ Permanent Magnets

C. Yttrium-Iron-Garnet
$\rightarrow$ Microwave isolation

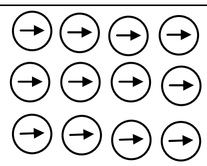
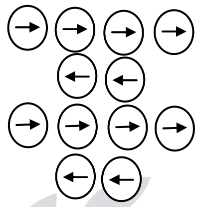
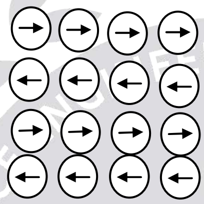
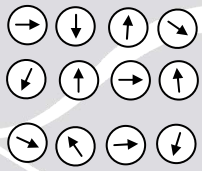
D. Mg-Zn Ferrite $\rightarrow$ Memory core

59. Ans: (c)

Sol: Permanent magnets are hard magnets. Electromagnets are soft magnets.

60. Ans: (b)

Sol:

Magnetic Material	Dipole arrangement	
1. Ferro magnet		All dipoles are aligned in one preferred direction and have equal magnitudes
2. Ferri magnet		Anti parallel with unequal Magnitudes
3. Anti ferro magnet		Anti parallel with equal magnitude
4. Para magnet		All the dipoles have equal magnitude with randomly oriented.

Conventional Practice Solutions

01. Ans: $4\pi \times 10^{-3}$ Amp -m

Sol: The magnetic moment (μ) of a current carrying coil is given by the formula

$\mu = niA$

where n = numbers of turns

i- current in the coil ; A = area of the coil

given n=500, I = 20mA and radius = 2cm

$\therefore \mu = 500 \times 20\times10^{-3}\times\pi\times4\times10^{-4}$

$= 4\pi \times 10^{-3}$ Amp -m

02. Ans: $4\pi\times10^{-2}$T, 1 A/m

Sol: The intensity of magnetization I = χH, where χ = susceptibility and H= intensity of magnetic field.

given $\chi = 1\times10^{-5}$ and H = 10^5A/m

$\therefore$ I = 1 A/m

The flux density B = $\mu_0\mu_r H$

μ_0 = permeability of free space = $4\pi \times 10^{-7}$

μ_r = relative permeability of the medium = $1+\chi$

Since χ is very small $\mu_r \approx 1$

Hence B = $\mu_0 H = 4\pi \times 10^{-7} \times 10^5$

$= 4\pi\times10^{-2}$T

03. Ans: 30.55 Amp – m²

Sol: Given the dipole moment of an Fe atoms = 1.8×10^{-23} Am^2

The density by Fe = 7.8 gm/ cc

Atomic weight of Fe = 55.85

Avogadro number = 6.023×10^{23} atoms per gram mole

No .of Fe atoms per CC $= \dfrac{6.023\times10^{23}}{55.85}\times7.81$

$= 8.487 \times10^{22}$ per CC

Volume of the specimen = 20CC

No. of Fe atoms is 20CC = $20\times8.487\times10^{22}$

Total dipole moment

$= 20\times8.487\times10^{22}\times1.8\times10^{-23}$

$= 30.55$ Amp – m^2

The which one of the digital specimen volume atoms is 2

04. Ans: 1000 A/m, μ_r = 2.5

Sol: Given I = 1500 A/m and B = $\pi\times10^{-3}$T.

To find H and μ_r .

The flux density B is related to magnetic field H as B = $\mu_0 H + \mu_0 I$

$\Rightarrow \pi \times10^{-3} = 4\pi \times10^{-7}H + 4\pi\times 10^{-7}H \times1500$

$\Rightarrow 1= 4\times10^{-4}H + 4\times0.15$

$\Rightarrow H = \dfrac{0.4}{4\times10^{-4}} = 1000 A/m$

$B = \mu_0\mu_r H \Rightarrow \pi \times10^{-3}$

$= 4\pi\times10^{-7} \times\mu_r \times1000$

$\Rightarrow \mu_r = 2.5$

05. Ans: 3.16×10^{-30}Am^2

Sol: The change is the magnetic moment of the electron revolving in a circular orbit under the action of a magnetic field is

$$\Delta\mu = \frac{e^2R^2B}{2m}$$

$$= \frac{2.56\times10^{-38}\times0.53^2\times10^{-20}\times40\times10^{-3}}{2\times9.1\times10^{-31}}$$

$= 3.16 \times10^{-30}$Am^2

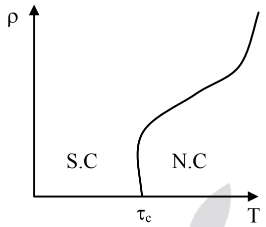
Chapter 4 Super conductors

Objective Practice Solutions

Level-1

01. Ans: (c)

Sol: Materials in which resistivity atrophy drops to zero value are called super conductors.



02. Ans: (a)

Sol: $\chi_m = \mu_r - 1$

In super conductor $\chi_m = -1$ (negative)

$\mu_0 = 0 \rightarrow$ super conductor has zero resistivity.

03. Ans: (c)

Sol: Most of the metals (Except cu, Ag, Au, Fe...etc) are become super conducting below a certain temperature which is characteristic of the particular metal so statement I is correct

Superconducting compounds and alloys have components, which is not superconducting nature. For example in YBCO (Yittrium Barium copper oxide) is a ceramic super conductor but in that component copper is not a super conductor.

04. Ans: (d)

Sol Based on BCS Theory (Bardeen-copper-Schrieffer) the superconductor have small energy gap of 0.001eV due to the presence of copper pairs and which generate lattice vibrations.

05. Ans: (b)

Sol: Both Type I and Type II SC have infinite conductivity in super conductor state only which gets destroyed above critical temperature and magnetic field**.**

06. Ans: (b)

Sol: In super conductor state,

$B = \mu_0 \quad (M + H)$

Susceptibility $\chi = \dfrac{M}{H} = -1$

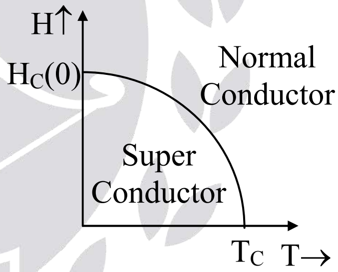
07. Ans: (d)

Sol: The critical field H_c depends on temperature

$$H_c = H_c(0)\left[1 - \frac{T^2}{T_C^2}\right]$$

at $T = 0$, $H_C = H_C(0)$

at $T = T_C$, $H_C = 0$



08. Ans: (d)

Sol Superconductivity of a material is destroyed by

1. Increasing the temperature above the critical temperature
2. Increasing the magnetic field above the critical magnetic field
3. Increasing the current above the critical current

09. Ans: (c)

Sol: $\chi = \mu_r - 1$; for SC $\chi = -1$; therefore $\mu_r = 0$

10. Ans: (d)

Level-2

01. Ans: (b)

Sol: Useful superconducting materials have very low critical temperatures.

02. Ans: (c)

Sol: Isotope effect in superconductors shows that, lattice vibration (phonons) also has some role in superconductivity.

03. Ans: (c)

Sol: Type I SC are also termed as soft SC which exhibit meissner effect and silsbee's rule.

04. Ans: (a)

Sol: $H_C(T) = H_C(0)\left[1-\frac{T^2}{T_C^2}\right]$

So, as temperature is decreased below critical temperature, value of critical magnetic field increases.

05. Ans: (a)

Sol Superconductivity of a material is destroyed by

1. Increasing the temperature above the critical temperature
2. Increasing the magnetic field above the critical magnetic field
3. Increasing the current above the critical current

06. Ans: (b)

Sol: Superconductors repel magnetic field due to the Meissner effect. Near the surface of the super conductor material small magnetic current flow (without any resistance) that make an opposite magnetic field that repels field from the magnet.

07. Ans: (c)

Sol: For a SC, susceptibility (χ_m) = −1

Relative permeability = 1 + χ_m =0

08. Ans: (d)

Sol: In a superconducting material

$$H = \frac{I}{2\pi r}$$

H↑ when I ↑ but below critical values of these quantities.

09. Ans: (a)

Sol Good conductors like silver, copper and gold do not show the superconductivity. Based on BCS (Bardeen-cooper-Schrieffer) theory electrons and phonons interaction leads to formation copper pairs in good conducting metals so that do not show the superconductivity.

10. Ans: (c)

Sol: $\chi = \mu_r - 1$; for SC $\chi = -1$; therefore $\mu_r = 0$

11. Ans: (c)

Sol: Critical field exists only below the transition temperature.

12. Ans: (d)

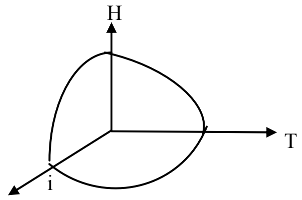
Sol Superconductivity of a material is destroyed by

1. Increasing the temperature above the critical temperature
2. Increasing the magnetic field above the critical magnetic field
3. Increasing the current above the critical current

13. Ans: (c)

Sol The critical current density of a super conductor depends on both temperature and applied magnetic field

$$H_c = H_0\left[1-\left(\frac{T}{T_t}\right)^2\right]$$

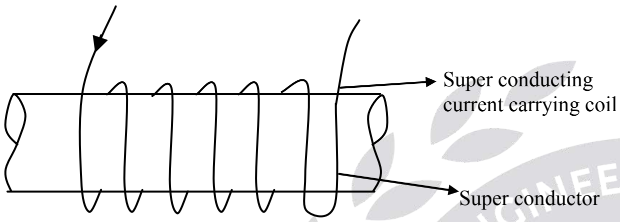


$i_c = 2\pi RH_c$

$$i_c = \frac{2\pi RH_c}{\pi R^2} = \frac{2H_c}{R}$$

14. Ans: (c)

Sol cryotron is a switch constructed by using superconductors



Cryotron switch is used to destroy the superconductivity

→ switching action is also characteristic of superconductors only

15. Ans: (c)

Sol: External magnetic fields are capable of destroying super conductivity. It is called critical field.

$$B_e = B_C(0)\left[1-\frac{T^2}{T_C^2}\right]$$

Thus critical field B_e depends on the T of the super conductor below T_C .

16. Ans: (a)

Sol: All superconducting materials have a specific critical temperature below which only they behave as superconductors

17. Ans: (c)

Sol. In superconducting state both entropy and thermal conductivity decreases because of presence of perfectness (zero defects) in a material, so statement I is correct.

Superconductivity results basically due to zero defects in a material and not because of zero atomic vibrations.

18. Ans: (c)

Sol: The magnetic field at which a super-conductor remains in its super conducting state at a temperature less than the transition temperature is less than the critical field corresponding to the given temperature.

19. Ans: (b)

Sol A superconductor is a perfect diamagnetic material because it's susceptibility is -1

A superconductor is a perfect conductor (or) zero resistivity Both assertion and reason are correct but reasons is not the correct explanation for assertion.

20. Ans: (b)

Sol To produce intense magnetic field by superconductor, the current should be less then the critical field.

$i_c = 2\pi RH_c$

Conventional Practice Solutions

01. Ans: 3.36×10^4 A/m, 1.986×10^4 A/m

Sol: Given the temperature T_c = 7.2K and the critical magnetic field at 0^0K,

$H_0 = 6.5\times10^4$ A/m

To calculate the critical field at 5 K and 6 K.

The critical field T^o K is given

$$H_c = H_0\left[1-\left(\frac{T}{T_c}\right)^2\right]$$

(i) at 5^0 K, $H_c = 6.5\times10^4\left[1-\left(\frac{5}{7.2}\right)^2\right]$

$= 3.36\times10^4$ A/m

(ii) at 6^0 K $H_c = 6.5\times10^4\left[1-\left(\frac{6}{7.2}\right)^2\right]$

$= 1.986\times10^4$ A/m

02. Ans: 14.74 K, 2.97×10^4 A/m

Sol: Given critical fields at T_1 = 10K as $H_{c_1} = 1.6\times10^4$ and at T_2 = 12K as $H_{c_2} = 1.0\times10^4$ A/m.

But we can calculate T_c and H_0 by solving the equation relating critical field and temperature.

$$1.6\times10^4 = H_0\left[1-\left(\frac{10}{T_c}\right)^2\right] \text{-------(1)}$$

and $$1.0\times10^4 = H_0\left[1-\left(\frac{12}{T_c}\right)^2\right] \text{-------(2)}$$

Dividing equation (1) by equation (2)

$$1.6 = \frac{T_c^2-100}{T_c^2-144}$$

T_c = 14.74K

Substituting for T_c in equation (1) we get

$$1.6\times10^4 = H_0\left[1-\left(\frac{10}{14.7}\right)^2\right]$$

$H_0 = 2.97\times10^4$ A/m

03. Ans: 251.2A

Sol: The critical current in related to the critical magnetic field as

$i_c = 2\pi rH_c$

Given r = 0.5mm, $H_c = 8\times10^4$ A/m

$i_c = 2\pi\times0.5\times10^{-3}\times8\times10^4$

i_c = 251.2A

04. Ans: 9×10^7 A/m^2

Sol: Given critical temperature T_c = 7.2K and critical field at 0^0K $H_0 = 6.5\times10^4$ A/m

Hence critical field H_c at 4^0K is given by

$$H_c = 6.5\times10^4\left[1-\left(\frac{4}{7.2}\right)^2\right] \text{-------(1)}$$

$= 4.5\times10^4$ A/m

The current density $J = \frac{i_c}{A} = \frac{2\pi rH_c}{\pi r^2} = \frac{2H_c}{r}$

$$J = \frac{2\times4.5\times10^4}{1\times10^{-3}} = 9\times10^7 \text{ A/m}^2$$

05. Ans: 292 AU

Sol: The London presentation depth λ is given by the expression $\lambda = \sqrt{\frac{m}{\eta_s e^2\mu_0}}$ where

m = mass of electron,

η_s = concentrating (or) super electron

e = electron charge

μ_0 = Permeability of free space

Given the density of lead = 11.36 gm/cc and atomic weight = 207.2

N-Avagadro number

$= 6.023\times10^{23}$ per gm-mole

$$\eta_s = \frac{6.023\times10^{23}}{207.2}\times11.38$$

$= 3.3\times10^{22}$ per – cc

$= 3.3\times10^{28}$ per m^3

$$\lambda = \sqrt{\frac{9.1\times10^{-31}}{3.3\times10^{28}\times2.56\times10^{-38}\times4\pi\times10^{-7}}}$$

λ = 292 AU

Chapter 5 Dielectric Materials

Objective Practice Solutions

Level-1

01. Ans: (a)

Sol: The dielectric strength of rubber is 40000 V/mm
f = 50 Hz
V = 33 kV

$$\frac{33\times10^3}{t} = \frac{40000}{10^{-3}}$$

$$\frac{33\times10^3\times10^{-3}}{40000} = t$$

$$t = \frac{33}{40000} = 8.25\times10^{-4}\text{ m} = 0.825\times10^{-3}\text{ m}$$

$= 0.825$ mm ≈ 0.833 mm

(or)

Dielectric strength of rubber is 40,000 V/mm thickness of the insulator required at 33kV is $t = \frac{33\text{kV}}{40\text{kV}} = 0.825\text{mm}$

02. Ans: (b)

Sol: Conductivity of insulating material is called as ionic conductivity.

03. Ans: (d)

Sol: Ferroelectric materials have already domains with permanent dipoles.
On application of electric field, they are aligned in the direction of electric field hence statement (I) is wrong. Statement (II) is correct.

04. Ans: (b)

Sol: Imaginary part of dielectric constant determines amount of loss or energy absorbed per m^3.

05. Ans: (a)

Sol: Electrostriction
→ Reverse effect of piezo electricity
Ionic conductivity
→ Conductivity of insulation
Peltier heat
→ Converse of seeback effect
Villari effect
→ Converse effect magnetostriction.

06. Ans: (c)

Sol: $\alpha_e = 4\pi\varepsilon_0 R^3$;
R → Radius of the atom

07. Ans: (b)

Sol: All ferroelectric materials are piezoelectric materials but all piezoelectric materials are not ferroelectric materials.

08. Ans: (c)

Sol: A dielectric when subjected to an alternating electric field, the dielectric constant is expressed as a complex quantity $\varepsilon_r^* = \varepsilon_r' - i\varepsilon_r''$ where, ε_r' is the real part and is $-i\varepsilon_r''$ is the imaginary part. Now the phase angle tan 'd' which gives energy dissipated in a dielectric is given as $\tan\delta = \frac{\varepsilon_r''}{\varepsilon_r'}$.

09. Ans: (c)

Sol: $\alpha_0 = \frac{P^2}{3kT}$

Quartz displays ferroelectric behavior and quartz crystal is formed by repeating silicon tetrahedrons.

10. Ans: (b)

Sol: The $BaTiO_3$ loose its ferroelectric property is above its Curie point.

11. Ans: (b)

Sol: Given data,

The relative dielectric constant $Al_2O_3 = 8$

Dielectric constant for free space = 8.854×10^{-12} f/m

C = ?

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$= \frac{8 \times 8.85 \times 10^{-12} \times 1000 \times 10^{-6}}{0.5 \times 10^{-6}} = 1.42 \times 10^{-7}$$

12. Ans: (b)

Sol: All Ferro electric materials are piezo electric but all Piezo electric materials are not Ferro electric.

13. Ans: (a)

Sol: Ferroelectric materials above the Curie temperature:

i. It is in the paraelectric state

ii. Its electric susceptibility is inversely proportional to its temperature

iii. Magnitude of electric susceptibility goes down by a factor of few hundreds in comparison to the value below the Curie temperature

14. Ans: (d)

Sol: The electric displacement $D = \varepsilon E + d.s$

$\varepsilon \rightarrow$ permittivity; $E \rightarrow$ electric field

$s \rightarrow$ strain; $d \rightarrow$ constant

these material called Piezo electric material.

15. Ans: (b)

16. Ans: (a)

Sol: The Piezo electrical properties of quartz are useful as a standard of frequency. Quartz clocks employ a crystal oscillator made from a quartz crystal that uses a combination of both direct & converse Piezo electricity to generate a regularly timed series of electric that used mark time.

17. Ans: (b)

Sol: Electronic polarization $\rightarrow 10^{15}$ Hz

Ionic polarization $\rightarrow 10^{13}$ Hz

Orientational polarization $\rightarrow 10^{12}$ Hz

Space charge polarization $\rightarrow 10^{2}$ Hz

18. Ans: (a)

Sol: Lead Zirconium Titanate can also be used in a record player

19. Ans: (c)

Sol: At high frequencies (optical) only electronic polarizability contributes. Ionic and orientational polarizabilities are not possible at optical frequencies.

20. Ans: (b)

Level-2

01. Ans: (c)

Sol: The coupling coefficient (K) = 0.32

Output mechanical energy = 7.06×10^{-3}J

= 7.06 mJ

$\therefore$ The applied electric field

E = (1 – 0.32) ×7.06 = 4.8mJ

02. Ans: (d)

Sol: The three polarization mechanism in dielectrics are electronic (bound), ionic & dipolar. Which are responsible for dielectric loses.

03. Ans: (d)

Sol: The overall mobility of a semiconductor, the present both impurity scattering (μ_I) and phonon scattering (μ_p) is $\mu_0 = \frac{\mu_I \times \mu_p}{\mu_I + \mu_p}$

04. Ans: (c)

Sol: The aluminum oxide used dielectric in electrolytic capacitors.

05. Ans: (b)

Sol: Given data,

$F = e\bar{E}$

$= 1.6 \times 10^{-19} \times \dfrac{2000}{1\times10^{-2}}$

$= 1.6 \times 2 \times 10^{-19} \times 10^{-5}$

$= 3.2 \times 10^{-14}$ N

06. Ans: (d)

Sol: Properties of insulators

DC uses:
1. Insulation resistance
2. Dielectric breakdown strength

AC uses:
1. Dielectric losses
2. Permittivity
3. Insulation resistance
4. Dielectric breakdown strength

07. Ans: (c)

Sol: given dielectric strength is 8 kV/mm. As the thickness of the paper is 0.05 mm, breakdown occurs at 8 kV/mm × 0.05 mm = 0.4 kV

08. Ans: (d)

Sol: In a parallel plate capacitors, let the charge be held constant while the dielectric material is replaced by different dielectric materials consider as storage energy, electric field intensity and capacitance.

09. Ans: (d)

Sol: The effective Q of the equivalent electric circuit of quartz crystal is of the order is 2 lakh.

10. Ans: (c)

Sol: refractive index $n = \sqrt{k} = \dfrac{c}{v}$

$k = \left(\dfrac{c}{v}\right)^2 = 9$

11. Ans: (d)

Sol: It is a related to the ratio between maximum storage energy and dielectric mean is called a quality factor.

12. Ans: (d)

Sol: Power loss or heat generated per second is

$$W = E^2 \ v \left[\frac{\varepsilon_r \ \tan\delta}{1.8 \times 10^{12}}\right] \ \text{Watt/cm}^3$$

13. Ans: (c)

Sol: Boltazmann constant

→ electron volt/Kelvin

Permeability of free space → Henry/meter

Permittivity of free space → Farad/meter

Mobility → cm^2/ volt-second.

14. Ans: (a)

Sol: The increase in applied frequency, dielectric loss in a material will increases

$$P = V^2 \ 2\pi f \ C \frac{\varepsilon_r''}{\varepsilon_r'}$$

15. Ans: (c)

Sol: Transformer or capacitor insulation is not used askarels because they decompose easily giving out toxic gases.

16. Ans: (*)

Both statements are false .

Barium titanate is ferroelectric, exhibits spontaneous polarization even in the absence of external electric field.

It has a large number of permanent dipoles even in the absence of external electric field. Its curie point is 361°K. Hence both are false

17. Ans: (a)

18. Ans: (a)

Sol: high humidity allows conduction and high temperature is the favorable condition chemical reactions.

19. Ans: (a)

Sol: Ferro electrical materials:

i. all domains are lined up in the direction of applied field giving rise to saturation

ii. if the field is reduced to zero, many domains remain aligned

iii. the remnant polarization can be eliminated only if the material is heated above Curie temperature

20. Ans: (b)

21. Ans: (a)

Sol: Ceramic insulators undergo a glazing process to reduce the possibility of electric breakdown it makes the surface non-absorbent.

22. Ans: (a)

23. Ans: (d)

24. Ans: (d)

Sol: Barium titanate & quartz is a Piezo electric material.

25. Ans: (c)

Sol: On the application of the field E, the modified field due to polarization P in solids and liquids having cubic symmetry is simplified by $E + \frac{P}{3\varepsilon_0}$.

26. Ans: (d)

Sol: The displacement of the positively charged nucleus and the (negative) electrons of an atom in opposite directions, on application of an electric field, result in electronic polarization.

It is present in all substances, independent of temperature, proportional to volume of the atom, fastest of all four, occurs upto optical frequencies and is complete.

27. Ans: (b)

Sol: $m\bar{x} = -ax - 2b\dot{x} - 2E_0 \cos \omega t$

In the above equation 'm' is the mass of the electron charge cloud and not of electrons and nucleus.

'a' restoring force constant

'b' damping constant due to the emission of radiation

$m\ddot{x}$ is the force acting on the electron cloud which gets displaced from its equilibrium position; no alteration of velocity of electrons orbiting the nucleus.

28. Ans: (c)

Sol: Ionic polarizability $\alpha_i = e^2 \omega^2 \left(\frac{1}{M_c} + \frac{1}{M_a}\right)$

29. Ans: (c)

Sol: $\alpha = 4\pi\varepsilon_0 R^3 + e^2 \omega^2 \left(\frac{1}{M_c} + \frac{1}{M_a}\right) + \frac{P^2}{3KT}$;

$$\frac{\varepsilon - 1}{\varepsilon + 2} = \frac{N\alpha}{3\varepsilon_0}$$

The dielectric constant of an insulator depends on frequency of the alternative field applied and temperature.

30. Ans: (b)

Sol: Ferromagnetism → An internal molecular field B_m which is proportional to magnetization M exist at each dipole and aligns it parallel to other dipole

Semiconductor → Doping with impurity increases the electrical conductivity

Optical property of solid → The conductivity of crystalline semiconductors and dielectric increased by radiation incident.

Super conductivity → DC electrical resistivity vanishes.

31. Ans: (d)

32. Ans: (d)

Conventional Practice Solutions

01. Ans: 2.82×10^7 V/m, 2.88×10^{-11} coulomb-m

Sol: The capacitance of a parallel plate capacitor is given by the expression.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

Given C = 8μF; A= 400cm^2 $\varepsilon_r = 8$; $\varepsilon_0 = 8.85\times10^{-12}$

We can calculate the separation d as

$$d = \frac{\varepsilon_0\varepsilon_r A}{C} = \frac{8.85\times10^{-12}\times8\times400\times10^{-4}}{8\times10^{-6}}$$

$= 35.4\times10^{-8}$m

When a potential difference of V is applied, the electric field E is given by

$$E = \frac{V}{d} = \frac{10}{35.4\times10^{-8}} = 2.82\times10^{7}\ \text{V/m}$$

To calculate the dipole moment induced, we find the charge induced

$Q = CV = 8\times10^{-6}\times10$

$= 8\times10^{-5}$ coulomb-m

Dipole moment induced $= 8\times10^{-5}\times35.4\times10^{-8}$

$= 2.88\times10^{-11}$coulomb-m

02. Ans: 1.4557

Sol: If there are N atoms per m^3 and α-the polarizability of the atom then the polarization $P = N\alpha E$, polarization is also related to the relative permittivity as

$P = \varepsilon_0(\varepsilon_r-1)E$.

$\varepsilon_0(\varepsilon_r-1) = N\alpha$

Given $\alpha = 1.5\times10^{-4}$ F-m^2

AT 0^{0}C and transformer pressure one mole of the substance occupies 22.4 litres of volume

$\Rightarrow 22.4\times10^{-3}$ m^3 contains 6.023×10^{26} atoms

$\therefore$ 1m^3 contains

$$N = \frac{6.023\times10^{26}}{22.4\times10^{-3}} = 2.69\times10^{28}$$

We have $\varepsilon_r - 1 = \frac{N\alpha}{\varepsilon_0}$

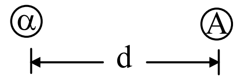
$$= \frac{2.69\times10^{28}\times1.5\times10^{-40}}{8.85\times10^{-12}} = 0.4557$$

$\varepsilon_r - 1 = 1.4557$

$\varepsilon_r = 1 + 0.4557 \Rightarrow 1.4557$

03. Ans: 3.2×10^{-32} coulomb-m

Sol:



Given the atom A at a distance

$\alpha = 30A^o$ from an α -particle

The α- particle is helium molecules.

It carries 2 units

of positive charge $q = 2\times1.6\times10^{-19}$C

The electric field intensity at the site of the atom $A = \frac{1}{4\pi\varepsilon_0}.\frac{q}{d^2}$

The dipole moment induced in the atom

$$= \alpha.\frac{1}{4\pi\varepsilon_0}.\frac{q}{d^2}$$

$$= 10^{-40}\times\frac{9\times10^9\times3.2\times10^{-19}}{900\times10^{-20}}$$

Dipole moment induced

$= 3.2\times10^{-32}$ coulomb-m

04. Ans: 1.6

Sol: As shown in the problem the ratio of E_{LOC} to the applied field E_0 is given by

$$\frac{E_{\ell oc}}{E_0} = \frac{1}{1-\frac{N\alpha}{3\varepsilon_0}}$$

Given $N = 5\times10^{28}$ and $\alpha = 2\times10^{-40}$

$\varepsilon_0 = 8.85\times10^{-12}$

$$= \frac{5\times10^{28}\times2\times10^{-40}}{3\times8.85\times10^{-12}}$$

$$\frac{N\alpha}{3\varepsilon_0} = 0.3765$$

$$\frac{E_{\ell oc}}{E_0} = \frac{1}{1-0.3765} = 1.6$$

05. Ans: 1.424A°

Sol: The dielectric constant ε_r is related to the polarizability as

$\varepsilon_0(\varepsilon_r - 1) = N\alpha$

Where N = Number of atoms per m^3

Given $\varepsilon_r = 1.00098$ and NTP the number of atoms per m^3 is 2.7×10^{25}

$$\alpha = \frac{\varepsilon_0(\varepsilon_r - 1)}{N}$$

$$\alpha = \frac{8.85\times10^{-12}\times0.00098}{2.7\times10^{25}}$$

But $\alpha = 4\pi\varepsilon_0 R^3$

$$R^3 = \frac{\alpha}{4\pi\varepsilon_0}$$

Hence $R^3 = \dfrac{8.85\times10^{-12}\times0.00098}{2.7\times10^{25}\times4\pi\varepsilon_0}$

$R = 1.424A^0$

Chapter 6 Ceramics & Composites

Objective Practice Solutions

Level-1

01. Ans: (c)
Sol: The atomic bonding in ceramics is partially ionic and partially covalent, with a predominantly ionic character.

02. Ans: (d)
Sol: Mechanical properties of fiber-reinforced composite is mainly influenced by
1. Properties of constituents
2. Interface strength
3. Fiber length, orientation, and volume fraction.

03. Ans: (d)
Sol: Wrong statement about ceramics**:**
They contain very less number of flaws like interior pores, Surface and interior cracks.

04. Ans: (d)
Sol: Abrasives are used to wear, grind or cut other materials, which are softer, Examples are diamond, silicon, carbide, tungsten, carbide, aluminum oxide, etc.

05. Ans: (d)
Sol: Ceramics are classified according to their crystal structure as AX, AX_2, ABX_3 and AB_2X_4 types.
Examples under each type are given below:
AX : NaCl, CsCl, Zns
AX_2: SiO_2, CaF_2, PuO_2, ThO_2
ABX_3: $BaTiO_3$, $SrZrO_3$, $SrSnO_3$
AB_2X_4: $MgAl_2O_4$, $FeAl_2O_4$

06. Ans: (d)
Sol: Ceramics have very high hardness values; they are the hardest known materials. Examples of ceramics of very high hardness values are silicon carbide, tungsten carbide, aluminum oxide, boron nitride, quartz, etc.

07. Ans: (a)
Sol: Composites are suitable for high temperature applications using Carbon-carbon composites.

08. Ans: (a)
Sol: 1. The elastic modulus of a composite increases with increasing volume fraction for any load
2. Under transverse load, the elastic modulus of composite is very low
3. Continuous fiber composites have high tensile strength for longitudinal load.

09. Ans: (b)
Sol: Composites in which the reinforcing fibres are long, extending over the entire length of the material are called continuous fibre composites. These composites are highly anisotropic, in the sense that their properties vary widely in different directions.

10. Ans: (a)
Sol: **ceramic materials:**
1 They are inorganic substances
2 They are brittle
3 They are good thermal insulators

Level-2

01. Ans: (a)
Sol: The structure of various types of silicates can be understood in terms of the arrangements of SiO_4 tetrahedron. Silicon is tetravalent and oxygen is divalent. Thus SiO_4 tetrahedron has a negative charge of 4 units. It is denoted by $(SiO_4)^4$.

02. Ans: (d)
Sol: Ceramic materials are refractories, abrasives & Glasses. Garnets is a composite material

03. Ans: (c)

Sol: If the radius ratio = 0.225, a more stable configuration is possible with four anions bonding with a cation as shown below. This configuration called the tetrahedral configuration, is stable for $0.225<x<0.414$. Here the cation occupies the void created by four anions forming a tetrahedral structure.

04. Ans: (a)

Sol: Cermets are large particle composites in which ceramic particles are embedded in a metal matrix.
These cermets are extremely hard materials and they are extensively used as cutting tools.

05. Ans: (b)

Sol: Concrete is a typical example of large particle composite in which the cement matrix is mixed with particulate of sand and gravel.

06. Ans: (c)

Sol: The three kinds of breakdowns possible in solid dielectrics are electrothermal, purely electrical and electrochemical.

Conventional Practice Solutions

01.

Sol: Ceramics are compounds made of oxides of metal and non-metals. They are characteristic by very high resistivity, low thermal conductivity very high melting point and large dielectric strength
These can be classified as

(i) those having a small relative permittivity, less than 12, called "dielectric ceramics"

Example: porcelains $\varepsilon_r \approx 4$ to 11, Mica – 5.7, alumina – 5.0, fused silica – 4.0 etc.

(ii) those having very large relative permittivity, called ferroelectric ceramics:
example: Rochelle' salt $\varepsilon_r = 500$, $BaTiO_3 = 1500$, PZT – 1500 etc.

Dielectric ceramics are mostly used as insulators and in capacitors. Porcelain is used in high voltage terminal parts, Mica is used to enclosed heating element. Alumina is used to make crucible and in furnaces. Ferroelectric are used as transducer and in miniaturization of electric circuits.

02.

Sol: A ceramic resonator is an electronic component are
That can produce oscillations at a specific frequency which combined with other appropriate components. It consists of a voltage variable capacitor that acts in the same way like quartz crystal. These are made of high stability piezoelectric ceramics, generally lead zinconate Titanate (PZT) which functions as a mechanical resonator. When voltage is applied its piezoelectric vibrations behaviour causes an oscillating signal. The thickness of the ceramic substrate determines the resonant frequency of the device.

Applications: these can be seen in many circuit boards since they an be used as the source of the clock signal for digital circuits such as microprocessors where the frequency accuracy is not of prime importance. They are also used in timing circuits in TVs, VCRs, telephones, voice synthesises, communication equipment etc. A ceramic resonator is often used in place of quartz crystal as a reference clock or signal generator in electronic circuit because of its low cost and smaller size.

03.

Sol: Polymers are giant molecules made by linking

Together a large number of small molecules called monomers. The reaction by which monomer units combine to form polymers is termed polymerization these are mainly three kinds of polymerization processes

(i) Addition polymerization

(ii) condensation polymerization and

(iii) copolymerization.

At high temperature and in the presence of catalyst like sulphuric acid or zinc chloride ethylene molecule polymenze to from polyethylene or polyltene during polymerization , the double bond is opened up into two single bound

```
H    H      H    H
|    |      |    |
C =  C →  – C –  C –
|    |      |    |
H    H      H    H
```

The monomers are bonded together end-to-end in a polymerization reaction

```
 H    H    H    H    H    H    H    H
 |    |    |    |    |    |    |    |
–C–   C–   C–   C–   C–   C–   C–   C–
 |    |    |    |    |    |    |    |
 H    H    H    H    H    H    H    H
```

The degree of polymerization defines the number of repeating monomers in the chain

Polymers have a wide range of user electrical insulation ropes and filaments carriages, sound proofing materials, vacuum seats, chemical wave, human body implants coating for flying panes polymeric clothing etc.

04. Preparation:

Sol: Polyvinylchloride are formed hydrochloride acid, lime stone and natural gas. It is manufactured by the addition polymerization of Vinylchloride, carried out in the presence of a catalyst under heat and pressure.

$$n\left(\begin{array}{c} H_2C = CH \\ \quad\quad | \\ \quad\quad cl \end{array}\right) \xrightarrow[\text{catalyst}]{\text{Heat/pressure}} \left(\begin{array}{c} H_2C = CH \\ \quad\quad | \\ \quad\quad cl \end{array}\right)_n$$

Polyvinyl chloride (PVC)

PVC can be manufactured in expand or cellular form. It is available in two forms, namely flexible and rigid.

Properties

1. They are strong, high resistant
2. They are resistant to acids and alkalise
3. It becomes soft beyond 80^0C
4. It is self extinguishing when ignited

Uses:

(i) cable jackets

(ii) lead wire insulation

(iii) It is a substitute for rubber.

(iv) corrugated roofing

(v) Pipes and fittings for water service cannot be used for hot water service.

05.

Sol: The number of repeating units in a polymer is called degree of polymerization. The molecule weight of the polymer is obtained by multiplying the molecule of the polymer is obtained by multiplying the molecule weight of monomer with degree of polymerization. For example let the molecule weight of polystyrene be 10,40,000. The molecular weight of a monomer of is 104 (formula C_8H_8). Hence degree of polymerization is 1000

Chapter 7 Nano Materials

Objective Practice Solutions

Level-1

01. Ans: (b)

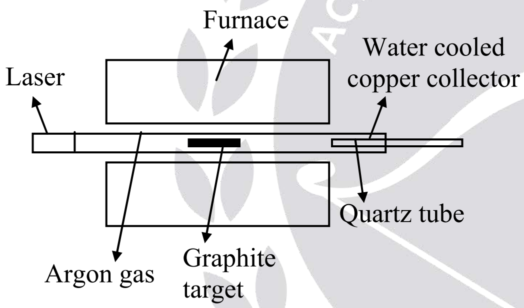
Sol: The nature of the bonding of a nanotube is described by applied quantum chemistry, specifically, orbit hybridization. Nanotubes are composed entirely of sp^2 bonds.

02. Ans: (d)

Sol:

i. Laser Evaporation Method :

The experimental arrangement for synthesizing carbon nanotubes by laser evaporation is as shown in the fig below.



The graphite target contain small amounts of cobalt and nickel that act as catalytic nucleation sites for the formation of the nanotubes.

An intense pulsed laser beam is incident on the target, evaporating carbon from the graphite, the argon then sweeps the carbon atoms from the high temperature zone to the colder copper collector on which they condense into nanotubes. Tubes 10-20mm diameter and 100 μm long can be made by this method. This method produces tubes with closed ends.

(ii) Carbon Arc Method: A potential of 20-25V is applied across carbon electrodes of 5-20 μm diameter and separated by 1mm at 500 torr pressure of flowing helium. Carbon atoms are ejected from the positive electrode and form nanotubes on the negative electrode. As the tubes form, the length of the positive electrode decreases, and a carbon deposit forms on the negative electrode. This method produce tubes with closed ends.

03. Ans: (c)

Sol: The tensile strength of carbon nanotubes is about 45 billion Pascal's. High strength steel alloys break at about 2 billion Pascal's. Thus carbon nanotubes are about 20 times stronger than steel.

04. Ans: (c)

Sol: Depending on the no.of dimensions If all 3 dimensions are in 'nm' range it is termed as quantum dots (nano particles (or) clusters)

05. Ans: (b)

Sol: Fe, Co and Ni are ferromagnetic in bulk form.

In Nano scale, they become super paramagnetic Both statements are correct.

06. Ans: (d)

Sol: Alkali metals like Na and K are paramagnetic in bulk form their nano clusters are ferro magnetic.

07. Ans: (d)

Sol: The optical properties of nano materials are different from that of corresponding bulk samples because of

(i) Quantum confinement effect of charge carriers in nano materials

(ii) Enhanced surface to volume ratio in nano materials

(iii) Charge and energy transfer is more efficient at the nano level.

08. Ans: (d)

Sol: Nano particles exhibit more magnetism than the particles of the Bulk because of

(i) Quantum confinement in the Nano particles.
(ii) large surface area to volume ratio of the nano particle.
(iii) Smaller value of the mean coordination number in the nano particle.

09. Ans: (d)

Sol: There are two different approaches of nanomaterial fabrication. One is the top – down approach and the other is the bottom – up approach. In top down technique generally a bulk material is taken and machined it to modify into the desired shape and product. Examples of this type of technique are the manufacturing of integrated circuits using a sequence of steps such as crystal growth, lithography, etching, ion implantation, etc. For nanomaterial synthesis ball – milling is an important top down approach, where microcrystalline structure are broken down to nanocrystalline structures, but original integrity of the material is retained.

Level-2

01. Ans: (a)

Sol: Generally, carbon nanotubes form as a mixture of semiconducting and metallic tubes in the ratio 2:1. The diameter and the chirality of a tube determine the conducting behavior of the tube. Chirality describes the manner in which the graphite sheet is rolled with respect to the axis vector. The metallic nanotubes have the armchair structure.

02. Ans: (a)

Sol: To produce single walled nanotubes, a small amount of cobalt, nickel, or iron is incorporated as a catalyst in the central region of the positive electrode. This method can produce single walled nanotubes of diameters 1-5nm with a length of 1 μm.

SWNTs are preferable using arc discharge method, the anode has to be doped with metal catalyst, such as Fe, Co, Ni, Y or Mo.

03. Ans: (c)

Sol: Chemical Vapor Deposition Method involves decomposing a hydrocarbon gas such as methane (CH_4) at 1100^0C. As the gas decomposes, carbon atoms are produced. Carbon atoms then condense on a cooler substrate that contains various catalysts such as iron. This method produced tubes with open ends.

04. Ans: (b)

Sol: Sol - gel is a wet – chemical – based self-assembly process for nanomaterial formation. The Sol-gel process, as the name implies, involves the evolution of networks through the formation of a colloidal suspensions (sol) and gelation of the sol to from a network in a continuous liquid phase (gel).

Once the gel is formed, there are several ways to convert this gel (inorganic network to the desired solid form. Depending on the deposition and drying processes or conditions, this gel can be converted into various forms such as aerogel, xerogel, gelled spheres, nano-powders, thin film coatings, nanostructured layers, etc.

05. Ans: (b)

Sol: In metal nano clusters the electrical conductivity gets enhanced these statement is wrong

06. Ans: (b)

Sol: The electric conductivity of a nano metallic sample is smaller than that of the corresponding bulk samples because.

(1). The density of states of conduction and valance bands decreases in Nano sample.

(2). The energy gap between the conduction and valance bands increases in the nano sample.

07. Ans: (b)

Sol: The reduction in the particle size in the case of semiconductors results in the increased in the bandgap which results in the shift of the light absorption towards in the high-energy region (blue shift). In addition, the band edge position of valance and the conduction bands are stabilized and destabilized respectively. The rate of recombination of photo excited electron hole pair is greatly reduced.

Conventional Practice Solutions

01.

Sol: Due to the unique physical-chemical properties of nano materials, they have a broad scope of application in medical and related fields, such as therapy of cancer cells, bio imaging, targeted therapy, drug delivery on the cellular level, and is the regeneration of tissues and organs. The table below give the practical application in medicine pharmacy and diagnostics.

Medicine	Pharmacy	Diagnostics
1. Regenerative medicine	1. Drug substance delivery	1. Bioimaging of cells, tissues and organs.
2. Photodynamic therapy	2. Drug toxicity reduction.	2. Medical analytics.
3. Bacteriology	3.Improvement of pharmaco kinetic properties of drug.	3. Molecular diagnostics.
4.Implantology		
5. Anti cancer therapy		

Bio imaging of tissues and organs usually involves quantum dots and nano particle. Certain optical properties of the nano materials, like fluorescence, make certain cells tissues are as visible when exposed to radiation at excitation wavelength. Quantum dots are characterised by higher photo-stability, wide absorption bond, narrow and symmetrical bond of fluorescence emission, high quantum efficiency and long fluorescence lifetime. These properties make quantum dots very popular in cancer cell imaging. Magnetic iron cobalt nano particles coated with gold are used in the magnetic resonance imaging (MRI).

Nano structures are finding extensive use in the drug delivery on cellular level. This helps better dissolution kinetics of drugs, quicker absorption and achieving the therapeutic concentration in the target tissues.

The unique architecture of nano materials allows then to initiate natural tissues and provide extra cellular environment for their growth and development.

Bone tissue regeneration has successfully employed the nano hydroxyapatite in the form of granules participating in the mineralization and proliferation.

02.

Sol: **Quantum well:** Reduction of size of a material upto the nano range only one dimension.

Eg: Thin films, Transistors, Graphene.

It is a 2-dimensional material.

Electrons flow take place only two directional.

Quantum wire: Reduction of size of a material upto the nano range only two dimension.

Eg: Thin wire, CNT.

- It is a 1-dimensional material.
- Electrons flow take place only one directional.

Quantum dot: Reduction of size of a material upto the nano range is all dimensions.

Eg: Drug delivery, Dendrimers.

- It is a zero-dimensional material.
- Electrons flow take place only all directional.

(or)

Quantum wells may be viewed as sandwiches consisting of a layer of material with small band gap embedded between two layers of materials with larger band gap. Such a double hetero structure confines carrier in to the small band gap material, thus realising in the growth direction, the "particle in a box". GaAs in sandwiched between $Al_xGa_{1-x}As$. While the bandgap of GaAs is 1.43 eV, that of aluminium gallium arsenide is 3.1 eV.

A narrow strip sliced from one of the planes is a 1-D quantum wire.

Dicing a 1-D wire yields a 0-D quantum dots.

03.

Sol: Nano electromechanical systems (NEMS) are a class of devices integrating electrical and mechanical functionality on the nano scale. This is the next stage of miniaturization after MEMS devices. NEMS integrate nano electronics devices with mechanical actuators, pumps, motors and thereby form physical, biological and chemical sensors

Due to large surface to volume ratio of nano materials, surface based sensing mechanics which are used to detect chemical substances in the air.

Due to nanometer range of device dimensions, it leads to high mechanical, resonance frequencies and potentially large quantum mechanical effects.

The most commonly used materials for NEMS are carbon nano-tubes which meet directly the needs of NEMS. The mechanical properties of carbon such as large young's modules are fundamental to the stability of NEMS. The metallic and semi-conducting properties of carbon based materials allow them to functions as transistors. Carbon nano-tubes have been used, as nano electronic interconnects as they can carry higher current densities

NEMS applications are envisaged in sensing displays, portable power generation, energy non vesting during delivery and imaging

Example of NEMS comprise nano-resonators, nano-accelerometers, integrated piezo resistive detector devices, ultra sharp tips for atomic force microscopy

04.

Sol: Electro-optic effect: It is the change in the optical properties of a material in response to an electro field that varies shortly compared with frequency of light.

They are

(i) change of absorption contacts in bulk semiconductors

(ii) creation of an absorption band at some wavelengths which gives rise to a change in colour.

A nano-sensor can detect

(i) a specific gas, hydrogen sulphide, ammonia, warfare gases.

(ii) a specific organic molecule such as an alcohol, fatty acid, lipid, or amino acid.

(iii) a change in pH, temperature, conductivity, or moisture.

The five nanotip in the case of atomic force microscope functions as a sensor to detect the corrugations on the surface of a nano material in its characterization.

Nano bio sensors are very useful in the targeted delivery of drugs in anti cancer treatment.

05.

Sol: Nano technology in health and medicine

Even today various disease like diabetes, cancer, Parkinson's disease, Alzheimer's disease, cardiovascular diseases and multiple sclerosis as well as different kinds of serious inflammatory or infectious diseases (e.g. HIV) constitute a high number of serious and complex illnesses which are posing a major problem for the mankind. Nanomedicine is an application of nanotechnology which works in the field of health and medicine. Nano-medicine makes use of nano materials, and nano electronic biosensors. In the future, nano medicine will benefit molecular nanotechnology. The medical area of nano science application has many projected benefits and is potentially valuable for all human races. With the help of nano medicine early detection and prevention, improved diagnosis, proper treatment and follow-up of diseases is possible. Certain nano scale particles are used as tags and labels, biological can be performed quickly, the testing has become more sensitive and more flexible. Gene sequencing has become more efficient with the invention of nano devices like gold nano particles, these gold particles when tagged with short segments of DNA can be used for detection of genetic sequence in a sample.

With the help of nanotechnology, damaged tissue can be reproduced or repaired. These so called artificially stimulated cells are used in tissue engineering, which might revolutionize the transplantation of organs or artificial implants.

Advanced biosensors with novel features can be developed with the help of Carbon nano tubes. These biosensors can be used for astrobiologyand can throw light on study origins of life. This technology is also being used to develop sensors for cancer diagnostics. Though CNT is inert, it can be functionalized at the tip with a probe molecule. Their study uses AFM as an experimental platform.

i. Probe molecule to serve as signature of leukemia cells identified.

ii. Current flow due to hybridization will be through CNT electrode to an IC chip.

iii. Prototype biosensors catheter development.

Nanotechnology has made excellent contribution in the field of stem cellresearch. For example, magnetic nanoparticles (MNPs) have been successfully used to isolate and group stem cells. Quantum dots have been used for molecular imaging and tracing of stem cells, for delivery of gene or drugs into stem cells, nano materials such as carbon nano tubes, fluorescent CNTs and fluorescent MNPs have been used. Unique nanostructures were designed for controllable regulation of proliferation and differentiation of stem cells is done by designed unique nano structures. All these advances speed up the development of stem cells toward the application in regenerative medicine [3]. The recent applications of nanotechnology in stem cell research promises to open new avenues in regenerative medicine. Nanotechnology can be a valuable tool to track and image stem cells, to drive their differentiation into specific cell lineage and ultimately to understand their biology. This will hopefully lead to stem cell-based therapeutics for the prevention, diagnosis and treatment of human diseases.

Nano devices can be used in stem cell research in tracking and imaging them. It has its applications for basic science as well as translational medicine. Stem cells can be modulated by mixing of nano carriers with biological molecules. Nano devices can be used for intracellular access and also for intelligent delivery and sensing of bio-molecules. These technologies have a great impact in stem cell microenvironment and tissue engineering studies and have a great potential for biomedical applications

06.

Sol: Nanosensors are nanoscale devices that measure physical .quantities and convert those quantities to signals that can be detected and analyzed. There are several ways being proposed today to make nanosensors; these include top-down lithography, bottom-up assembly, and molecular self-assembly. There are different types of nanosensors in the market and in development for various applications. Though all sensors measure different things, sensors share the same basic workflow: a selective binding of an analyte, signal generation from the interaction of the nanosensor with the bio-element, and processing of the signal into useful metrics.