**EASWARI ENGINEERING COLLEGE 13.02.2024**
**(AUTONOMOUS)**
**I YEAR BE/B. Tech (II SEM)**
**QUESTION BANK**
**ELECTRICAL ENGINEERING MATERIALS -231PYB204T**
**(For EEE)**

## UNIT I – CONDUCTIVITY OF METALS
## PART – A

**1. What are the special features of free electron theory of metals? (*AU Dec 2016*)**

The classical free electron theory visualizes a metal as an array atoms (icons) premeated by a gas of free electrons. There is no mutual interaction among the free electrons or between ions & electrons. The free electrons can move freely in random directions under the constant potential provided by the fixed ions of the lattice.

**2. What are failures of classical free electron theory? (*AU June 2013, Dec 2015*)**

i. It predicated that the value of electronic specific heat as 3/2 R. But experimentally it is about 0.01R only.
ii. The ratio between thermal conductivity and electrical conductivity is not constant at low temperatures.
iii. The theoretical value of paramagnetic susceptibility is greater than the experimental value.
iv. The electrical conductivity of semiconductors, ferromagnetism, the photoelectric effect and black body radiation cannot be explained.

**3. What are the important applications of quantum free electron theory?**

Here the wave aspect of electrons is taken into account. Particularly the fermi level electrons are responsible for electrical conductivity and thermal conductivity. Hence the correct values of electrical and thermal conductivities and electronic specific heat are obtained.

**4. Define Fermi level and Fermi energy with its importance.**

**Fermi level** is the energy level at finite temperature above 0K in which the probability of the electron occupation is ½ and it is also the level of maximum energy of the filled states at 0K

**Fermi energy** is the energy of the state at which the probability of the electron occupation is ½ at any temperature above 0K.It is also the maximum energy of filled states at 0K.

**Importance:** Fermi level and Fermi energy determine the probability of an electron occupying a given energy level at a given temperature.

**5. Define density of states. What is its use? (*AU June 2013, June 2016*)**

Density of states is defined as the number of energy states per unit volume in an energy interval. It is used to calculate the number of charge carriers per unit volume of the solid.

**6. What is an energy band?**

A set of closely spaced energy levels is called an energy bond.

**7. Define band gap, valence band & conduction band.**

**Band gap** is the energy difference between the minimum energy of conduction band and the maximum energy of valence band. Those energies lying in the band gap are not allowed to occupy by the electrons of that solid.

**Valence band** is the region of energy levels where the valence electrons occupy their positions.

**Conduction band** is the region of energy levels where the conduction electrons or free electrons occupy their positions.

**8. What are holes?**

Holes are the vacant sites in the valence band of a solid. These will behave like positive charge carriers having the mass of electron in the presence of applied electric field.

**9. Define effective mass of electron.**

Effective mass of electron 'm*' is the mass of the electron when its moving through the periodic lattice.

For example, in copper m*> m where m is the rest mass of an electron.

**10. State the relation between thermal conductivity and electrical conductivity. Does it hold good for all types of materials.**

$K / \sigma = LT$ where L is a constant called **Lorentz number** and T is the temperature of metal in Kelvin. This relation holds only for metals. At low temperatures this relation is not true even for metals.

**11. Explain thermal conductivity.**

Thermal conductivity of a material 'K' is equal to the amount of heat flowing power unit through the material having unit area of cross section and maintaining a unit temperature gradient. In general the total thermal conductivity of a solid is the sum of thermal conductivity due to free electrons and thermal conductivity due to photons (lattice vibrations)

i.e., $K_{total} = K_{electron} + K_{photon}$

In metals, $K_{electron} >> K_{photon}$

In non-metallic conductors, $K_{photon}$ is a dominating one.

Example: Diamond at 30 K is a better thermal conductor than silver at 30 K.

But in insulators, $K_{total} = K_{photon}$.

The thermal conductivity of a metal increase exponentially from 0 K to 20 K and then decreases with increase of temperature.

**12. What are the sources of electrical resistance in metals?**

i) Lattice defects and ii) thermal vibrations of the lattice.

When the electron is moving through a perfect periodic lattice, there is no resistivity except temperature dependent resistivity. The impurities and residual defects produce so many scattering centers and reduce the mean free path of electrons. Similarly if the vibration amplitude increases with the increase of temperature, the mean free path of electron decreases. Hence the resistivity increases.

**13. Give the microscopic form of ohm's law in a metallic conductor. Whether the ohm's law is true at all temperatures?**

**J = σ E**

Where **J** is the current density, σ is the electrical conductivity and **E** is the electric field intensity.

The ohm's law is not true at all temperatures in a conductor, since the resistance of a conductor varies with temperature in a complicated manner at different range of temperatures.

**14. Define drift velocity. How is it different from thermal velocity of an electron? (*AU Dec 2015*)**

The drift velocity is defined as the average velocity acquired by an electron in the presence of an electric field $V_d = J / ne$

The thermal velocity is random in nature and is very high ($10^5$ m/s). But the drift velocity $i_d$ directional one and is very small (50 cm/s).

**15. Define relaxation and collision time of free electrons in a metal. (*AU Dec 2012*)**

**Relaxation time** is defined as the time taken by an electron to reach equilibrium position from its disturbed position in the presence of electric field. **The collision time** is defined as the average time taken by an electron between two successive collisions. For an isotropic collision, the relaxation time and collision time are equal.

**16. Distinguish between conductor and semiconductor on the basis their electrical conductivity.**

**Conductor** has electrical conductivity of $10^4$ to $10^9$ $ohm^{-1}m^{-1}$ and semiconductor has electrical conductivity of $10^3$ to $10^4$ $ohm^{-1}m^{-1}$. For conductors, the electrical conductivity is decreased with respect to addition impurities and increase of temperature due to decrease in mean free path. But in **semiconductors**, the electrical conductivity is increased with respect to addition of impurities and increase of temperature due to increase of charge density.

**17. Aluminium has three valence electrons and copper has one valence electron. Why do we have large electrical conductivity for copper than Aluminium?**

Based on quantum electron theory, even though aluminium has three times as many conduction electrons as copper, the area of the fermi surface in aluminium is about the same in copper. But the number of uncompensated electrons in the fermi surface of copper is more than the number of uncompensated electrons in the fermi surface of aluminium.since the value of the electrical conductivity depends on the number of compensated electrons, copper has higher electrical conductivity than aluminium.

**18. State Widemann – Franz law. (*AU May 2015*)**

The ratio between thermal conductivity and electrical conductivity of a metal is a constant at a given temperature.

i.e., $K / \sigma T = L$ (constant)

where K and σ are thermal conductivity and electrical conductivity respectively.

**19. Discuss the variation of resistivity of a metal with respect to variation of temperature.**

At very low temperatures, the resistivity is almost constant and its value in very small. From the low temperature to the Debye temperature of the metal, the resistivity varies in a non-linear manner. i.e., $\rho \alpha T^5$. Above Debye temperature $\rho \alpha T$.

**20. What is Electron Theory of solids?**

The Electrons in the outermost orbit of the atoms which constitute the solids determine its electrical properties. The electron theory of solids explains the structure and properties of solids through their electronic structure.

**21. What is periodic potential?**

When an electron moves through a solid, its potential energy varies periodically with the periodicity equal to period of space lattice 'a' (interatomic distance).This is called periodic potential.

**22. State and explain Bloch Theorem.**

The Schrodinger equation is

$$\frac{d^2\psi}{dx^2} + \frac{2m}{h^2}[E-V(x)]\,\psi = 0$$

With reference to the solution of this equation, there is an important theorem which states that these exist solutions of the form.

$$\Psi(x) = e^{\pm ikx} u_k(x) \text{ where } u_k(x) = u_k(x+\alpha)$$

Where $\alpha$ is the period,

Thus the solutions are plane waves modulated by the function $u_k(x)$,
which has the same periodicity as the lattice. This theorem is known as the Bloch Theorem.

**23. Define mean free path.**

The average distance traveled by a free electron between any two successive collisions in the presence of an applied field is known as mean free path. It is the product of drift velocity of the electron (vd) and collision time ($\tau$)

$$\lambda = v_d \times \tau_c$$

## PART – B & C

1. State and prove the Widemann – Franz law. (*AU May 2014*)
2. Deduce a mathematical expression for electrical conductivity and thermal conductivity of a conducting material and hence obtain Widemann-Franz law. (*AU Dec 2015, May 2018*)
3. Derive an expression for electrical conductivity in a material in terms of mobility of electrons. How does the conductivity vary with temperature?
4. (i) Derive an expression for density of states. (*AU Dec 2016*)
   (ii) State the merits and demerits of classical free electron theory.
5. Define Fermi energy. Obtain a general expression for the Fermi energy of electrons in solids at zero degree Kelvin. Show that at the same temperature the average energy of the electron is $(3/5)^{th}$ of the Fermi energy.
6. (i) Define Fermi energy.
   (ii) Explain Fermi Dirac distribution for electrons in a metal.
7. Derive an expression for the density of states and based on that calculate the carrier concentration in metals. (*AU May 2017*)
8. Write short notes on (i) Energy levels (ii) Energy bands (iii) Bound and free electrons (iv) Electronic work function.
9. State and explain Bloch Theorem.
10. Explain periodic potential and show that it reaches to energy band structures.
11. Describe the formation of energy band in a crystalline solid.

**12.** Explain the origin of energy band in a solid.
**13.** Describe tight binding approximation to explain the formation of energy band.
**14.** Derive an expression for the effective mass of an electron moving in energy bands of a solid. Show how it varies with the wave vector.
**15.** Explain the concept of hole.
**16.** Define valance band, conduction band, and forbidden energy gap in the energy band structure.
**17.** Distinguish between conductor, semiconductor and insulator.

## UNIT-II DIELECTRIC PROPERTIES OF INSULATORS IN STATIC AND ALTERNATING FIELD

## PART – A

**1. Define polarization of a dielectric material.**

The process of the producing electrical dipoles inside the dielectric by the application an external electrical field is called polarization in dielectrics.

Induced dipole moment ($\mu$) = $\alpha E$

E →Applied electrical field

$\alpha$ → Polarizability

**2. Mention three important liquid dielectric materials.**

i. Transformer oil
ii. Askarels
iii. Silicon liquid

**3. Name the four polarisation mechanisms.**

i. Electronic polarisation.
ii. Ionic polarisation.
iii. Orientational polarisation.
iv. Space- charge polarisation.

**4. What is electronic polarisation?**

Electronic polarisation means production of electric dipoles by the applied electric field .It is due to shifting of charges in the material by the applied electric field.

**5. What is ionic polarisation?**

Ionic polarisation is due to the displacement of cations (negative ions) and anions (positive ions) in opposite direction due to the application of an electrical field. This occurs in an ionic solid.

**6. What is orientation polarisation?**

When an electrical field is applied on the dielectric medium with polar molecules, the dipole align themselves in the field direction and thereby increases electric dipole moment. Such a type of contribution to polarisation due to the orientation of permanent dipoles by the applied field is called **orientation polarisation.**

**7. What is space- charge polarisation?**

In some materials containing two or more phases, the application of an electrical field causes the accumulation of charges at the interfaces between the phases or at the electrodes. As result of this, polarisation is produced. This type of polarisation is known as **space charge polarisation.**

**8. Define dielectric loss and loss tangent.**

When a dielectric material is subjected to an A.C voltage, the electrical energy is absorbed by the material and is dissipated in the form of heat. This dissipation of energy is called **dielectric loss.**

In a perfect insulator, polarisation is complete during each cycle and there is no consumption of energy and the charging current leads the applied voltage by $90^0$. But for commercial dielectric, this phase angle is less than $90^0$ by an angle and is called dielectric loss angle. Tan is taken as measure of dielectric loss and is known as **loss tangent.**

**9. Define dielectric breakdown and dielectric strength.**

Whenever the electrical field strength applied to a dielectric exceeds a critical value, very large current flows through it. The dielectric loses its insulating property and becomes conducting. This phenomenon is known as dielectric breakdown. The electrical field strength at which dielectric breakdown occurs is known as **dielectric Strength.**

**10. Mention the various breakdown mechanisms.**

i) Intrinsic breakdown and avalanche breakdown
ii) Thermal breakdown
iii) Chemical and Electrochemical breakdown
iv) Discharge break down
v) Defect breakdown

**11. What is intrinsic breakdown?**

For a dielectric, the charge displacement increases with increasing electrical field strength. Beyond a critical value of electrical field strength, there is an electrical breakdown due to physical deterioration in the dielectric material.

**12. What is thermal breakdown?**

When an electrical field is applied to a dielectric material, some amount of hear is produced. This heat must be dissipated from the material.

In some cases, the amount of hear produced is very large as compared to the heat dissipated. Due to excess of heat the temperature inside the dielectric increases and may produce local melting in the dielectric material.

During this process, a large amount of current flows through the material and causes their dielectric to breakdown. This type of breakdown is known as thermal breakdown.

**13. What is chemical and electrochemical breakdown?**

Electro chemical breakdown is similar to thermal breakdown. When the temperature of a dielectric material increases, mobility of ions increases and hence the electrochemical reaction may take place.This leads to leakage current and energy loss in the material and finally dielectric breakdown occurs.

**14. What is discharge break down?**

Discharge breakdown occurs when a dielectric contains occluded gas bubbles. When this type of dielectric is subjected to electric field; the gases present in the material will easily ionize and thus produces large ionization current. The gaseous ions bombard the solid dielectric. This causes electrical deterioration and leads to dielectric breakdown.

**15. What is defect breakdown?**

The surface of the dielectric material may have defects such as cracks, porosity and blowholes. Impurities like dust or moisture may collect at these discontinuities (defects). This will lead to a breakdown in a dielectric material.

**16. What are requirements of good insulating materials?**

The good insulating materials should have

i) High electrical resistivity to reduce leakage current.
ii) High dielectrical strength to with stand higher voltage.
iii) Smaller dielectric loss
iv) Sufficient mechanical strength.

**17. Compare active and passive dielectrics.**

**Active dielectrics**

Dielectrics which can easily adapt itself to store the electrical energy in it is called active dielectrics.

**Examples:** Piezo electric ,Ferro electrics

It is used in the production of ultrasonics.

**Passive dielectrics.**

Dielectric which restricts the flow of electrical energy in it is called passive dielectrics.

**Examples:** Glass, mica, plastic

It is used in the production of sheets, pipes, etc.

**18. What are ferro-electric materials? Give examples.**

Materials which exhibit electronic polarization even in the absence of the applied electrical field are known as ferro-electric materials.

**Examples:** Barium Titanate ($BaTiO_3$), Potassium Dihydrogen Phosphate ($KH_2PO_4$)

**19. What are the differences between polar and non-polar molecules?**

**Polar molecule**

1. These molecules have permanent dipole moments even in the absence of an applied field.

2. The polarization of polar molecules is highly temperature dependent.
3. These molecules do not have symmetrical structure and they do not have centre of symmetry.
4. For this kind of molecules, there is absorption or emission in the infrared range.
5. Examples: CHCl3,HCl

**Non-polar molecules**

1. These molecules do not have permanent dipole moments
2. The polarization of polar molecules is temperature independent.
3. These molecules have symmetrical structure and they have centre of symmetry.
4. For these molecules, there is no absorption or emission in the infrared range.
5. Examples: CCl4, CO2

**20. What is meant by pyro-electricity?**

It means that, the creation of electronic polarization by thermal stress.

**21. What is meant by dielectric breakdown? (*AU June 2012*)**

Dielectric breakdown is the failure of the material at which the dielectric loses its insulation resistance and permits large currents to pass through it.

**22. What are dielectrics? (*AU May 2011*)**

Dielectrics are the materials having permanent electric dipoles or having the ability to produce enormous induced dipoles in the presence of applied electric field.

**23. What is meant by local field in a dielectric?**

The local field in a dielectric is the space and time average of the electric field acting on a molecule or atom of the dielectric kept in an applied electric field. It is equal to

$E_i = E + P/3\varepsilon_0$ for simple elements dielectrics.

Here, E = applied field strength and

P = polarization field produced in the dielectric.

**24. Define dielectric constant. (*AU May 2011*)**

Dielectric constant is the measure of the polarization in a material. It is also called relative permitivity '$\varepsilon_r$' of the material.

Thus, $\varepsilon_r = E_o / (E_o - E_p)$

Where $E_o$ = applied electric field.

$E_p$ = produced polarization field.

If there is more polarization in a medium then $E_p$ is more and $\varepsilon_r$ is higher for that medium.

**25. Define electric polarization.**

Electric polarization means production or inducement of electric dipoles by the applied electric field. It is due to shifting of the charges in the material by the applied electric field. It depends upon frequency of the applied field and temperature.

**26. Define dielectric strength. (*AU June 2012*)**

Dielectric strength is the minimum voltage required per unit thickness of the material to produce dielectric breakdown or dielectric failure. Unit: V / m

**27. Explain the important properties associated with the dielectrics.**

i. **Ferro electricity**: Property by which dielectric materials exhibit electric polarization even in the absence of applied electric field.
ii. **Piezo electricity**: Property by which electric polarization is produced by mechanical pressure.
iii. **Pyroelectricity**: Property by which electric polarization is produced by thermal energy.

## PART - B & PART - C

**1.** (i) Describe the different types of polarization. (*AU May 2011*)
(ii) Obtain an expression for electronic and ionic polarization in dielectrics.
**2.** Starting with the internal field expression, derive Clausius-Mosotti equation. (*AU June 2010*)
**3.** (i) What is meant by internal field? (*AU June 2009*)
(ii) Obtain expression for internal field using Lorentz method.
(iii)The dielectric constant of water is 80. Is water a good dielectric? It is for energy storage in capacitors? Justify your answer.
**4.** (i) Give a detailed discussion on the various types of dielectric breakdown in dielectric materials.
(ii) What are the remedies to avoid breakdown mechanism? (*AU June 2009*)
**5.** Describe the application of dielectric materials in capacitor and transformer. (*AU June 2010*)
**6**. Write short notes on ferroelectricity and its application.

## UNIT – III MAGNETIC PROPERTIES AND SUPERCONDUCTIVITY

## PART – A

**1. What are the essential differences between hard and soft magnetic materials?**

| Sl.No. | Hard magnetic material | Soft magnetic material |
|---|---|---|
| **i.** | It has large area hysteresis Loop. | It has smaller area hysteresis loop |
| **ii.** | It has high coercivity and high retentivity. | It has less coercivity and lesser retentivity. |
| **iii.** | It has irreversible domain wall movement. | It has reversible domain wall movement. |
| **iv.** | It has lesser permeability. | It has large permeability. |
| **v.** | It is used for making permanent magnets. | It is used for making electromagnets. |

**2. Explain the terms remenance and coercivity.**

**Remenance** is the property of the magnetic material by which it retains some magnetization when the magnetizing field is reduced to zero. It is expressed in terms of weber/$m^2$. **Coercivity** is the property of the magnetic material by which it requires a demagnetizing force to destroy the residual magnetism in it. It is expressed in terms of ampere turn/m.

**3. Name two uses of soft magnetic materials.**

i. Since soft magnetic materials can be easily magnetized or demagnetized, these are used to make electromagnets used in cranes.
ii. Due to their low hysteresis loss, they are also used as transformer core materials.

**4. What are the requirements of transformer core material?**

Transformer core material should have high resistivity to reduce eddy current losses and magnetically soft to reduce hysteresis losses.

**5. What are magnetostriction materials?**

Magnetic materials whose length along the axis of magnetization may change when it is placed parallel to the magnetic field are called magnetostriction materials. These are used to produce ultrasonic waves and design mechanical filters used in the single side band transmission of ratio waves.

**6. Give the origin of magnetic moment in magnetic materials.**

The magnetic moment originates from the orbital motion and spinning motion of electrons in atoms. Particularly ferromagnetism is mainly due to spin-spin interaction of unpaired electrons in the ferromagnetic atoms.

**7. What is mean by energy product of a hard magnetic material?**

The product of residual magnetic induction ($B_r$) and coercively ($H_c$) is called energy product. It is the important quantity to design powerful permanent magnets. For example Alnico magnets have high energy products and hence they are very powerful permanent magnets.

**8. For making electromagnet, what is nature of magnetic material.**

For making electromagnets we require high initial permeability, low coercivity and low hysteresis loss magnetic materials.

**Example:** Perm alloy

**9. What are ESD magnets? What are they properties?**

ESD magnets are elongated simple domain magnets. These have very fine particles with larger magnetization. These are stable towards their magnetic properties and have a single domain structure.

**10. How do you get high-energy product in a hard magnetic material?**

Making irreversible domain wall movement by introducing voids or internal stresses inside the magnetic material, one can make hard magnetic material used for making powerful permanent magnets.

**11. What are domains? (*AU Dec 2009*)**

Domains are the small regions in a ferromagnetic material, which are completely magnetized by favourable exchange spin-spin interaction. The domains are responsible for large magnetization of ferromagnetic materials with very weak magnetic fields.

**12. What is Meissner effect in superconductors?**

Meissner effect refers to the complete exclusion of magnetic flux inside the superconductor when it is placed in a uniform magnetic field. Thus it indicates that superconductors are perfect diamagnetic.

**13. What are the different types of superconductors?**

Based on critical temperature, there are type I superconductor (soft superconductor) having complete Meissner effect or only one critical magnetic field (Examples: Al, Zn, Ga) and type II superconductor (hard superconductor) having incomplete Meissner effect or two critical magnetic fields between which the material is in the mixed state. (Example: Zr, Nb). Further there are p-type superconductors or high temperature superconductors in which charge carries are holes and n-type superconductors or low temperature superconductors in which charge carries electrons.

**14. Mention few applications of superconductors.**

i. Superconducting transmission system is used for transmission of electric energy with very low transmission loss.
ii. Superconducting magnets are used for producing very large magnetic field and for magnetic levitation.
iii. Cryotrons superconducting gating circuits act as switching elements in computers.
iv. Using superconducting components one can design an extremely fast and large scale computer occupying lesser volume and consuming electrical electrical energy less than ½ watt.

**15. Explain the term superconductor.**

Superconductor is the material having nearly zero resistivity and perfect diamagnetism. Thus a superconductor can conduct electric current without any resistance and excludes the magnetic flux from the material when it is placed in a magnetic field.

**16. What is meant by superconducting transition temperature?**

Superconducting transition temperature is the temperature at which normal material is converted into superconducting one when we cool the material.

**17. What is D.C Josephson effect?**

When two superconducting blocks of different materials like aluminum and tin are kept at liquid helium temperature and separated by a small gap of the order of few Å and are connected externally by a wire, a direct current flows in the external circuit. This is called D.C Josephson effect.

**18. How will you design a microwave oscillator using superconductors?**

When two superconducting blocks of same material like aluminum are kept at liquid helium temperature and separated by a small gap of order of few Å or a thin insulating layer and are connected to a D.C power supply, microwaves emanate from the gap or junction. Since a.c. microwaves are produced, this effect is called A.C.Josephson effect.

**19. What is the effect of magnetic field on a superconductor?**

When a superconductor is in the superconducting state and the applied magnetic field is greater than the critical, the magnetic flux enters in to the material and it becomes normal material. The critical field $H_c$ depends on the temperature of the superconducting material such that $H_c = H_0 [1 - T^2 / T_c^2 ]$ where $H_o$ = critical field at 0 K and $T_c$ is the superconducting transition temperature.

**20. What is a cryotron?**

Cryotron is a switching element made from two different superconductors arranged in a manner that one superconductor in the form of a straight wire is enclosed by another superconducting coil and is based on the disappearance of superconducting state in a superconductor due to the production of magnetic field by the other superconductor surrounding the first superconductor.

**21. How will you explain the phenomenon of superconductivity?**

High temperature superconductivity can be explained by resonance valence bond theory such that attractive correlation brings intense electron pairing similar to that responsible for bonding hydrogen atoms in a hydrogen molecule. Low temperature superconductivity explained by BCS theory such that superconductivity is due to cooper pairs of electrons having opposite spins. At very low temperatures, cooper pair is formed through electron-electron interaction via lattice deformation.

**22. What are critical temperature, critical magnetic field and critical current in the case of superconductivity?**

**Critical temperature** '$T_c$' is the temperature below, which the material behaves as superconductor.

**Critical magnetic field** '$H_c$' is the minimum value of the magnetic field required to destroy superconductivity existing in the material at a temperature below its critical temperature.

$H_c = H_0 [1 – (T/T_c)^2 ]$

**Critical current** '$I_c$' is the minimum current required to destroy superconductivity existing in the material at a temperature below its critical temperature.

**23. What are SQUIDS? What are their uses?**

**Superconducting Quantum Interference Devices** (SQUIDS) are based on the flux quantization in a superconducting ring and is a double junction quantum interferometer formed from two Josephson junctions mounted on a superconducting ring. SQUID sensors have high sensitivity at low temperatures and are used to detect defects in heart and brain through magneto cardiography and magneto encephalography.

**24. Define the term intensity of magnetization and flux density? (*AU May 2018*)**

**Intensity of Magnetization:**

The term magnetization is the process of converting non magnetic material into magnetic material. It measures the magnetization of the magnetized specimen.

$M=M_{\mu}/V$ weber/m$^2$

**Magnetic flux density:**

It is defined as the number of magnetic lines of force passing normally through unit area of cross section A at that point.

$B=\phi_m/A$ Weber /m$^2$

**25. Mention the energies involved in the origin of domains in ferro magnetic materials. (*AU May 2018*)**

1.Exchange energy

2.Anisotropy energy

3.Domain wall energy

4.magnetostrictive energy

**26. On the basic of spin how the materials are classified as para, ferro, antiferro and ferrimagnetic.**

(i) Paramagnetic materials have few unpaired electron spins of equal magnitudes.
(ii) Ferro magnetic materials have many unpaired electron spins with equal magnitudes.
(iii) Anti ferro magnetic materials have equal magnitude of spins but in antiparallel manner.
(iv)Ferrimanetic materials have spins in antiparallel manner but with unequal magnitudes.

**27. What is Bohr magneton?**

The orbital magnetic moment and the spin magnetic moment of an electron in an atom can be expressed in terms of atomic unit of magnetic moment called **Bohr magneton.**

**28. What is ferromagnetism?**

Certain materials like iron (Fe), Cobalt (Co), Nickel (Ni) and certain alloys exhibit **Spontaneous magnetization** ie., they have a small amount of magnetization (atomic moments are aligned) even in the absence of an external magnetic field.This phenomenon is known as ferromagnetism.

**29. What are ferromagnetic materials?**

The materials which exhibit ferromagnetism are called as ferromagnetic materials.

**30. What are the properties of ferromagnetic materials?**

(i) All the dipoles are aligned parallel to each other due to the magnetic interaction between any two dipoles.
(ii) They have permanent dipole moment. They attract the magnetic field strongly.
(iii) They exhibit magnetisation even in the absence of magnetic field. This property of ferromagnetic materials is called as **spontaneous magnetization.**

**31. What is domain theory of ferromagnetism?**

According to domain theory, a virgin specimen of ferromagnetic materials consists of a number of regions or domains which are spontaneously magnetized due to parallel alignment of all magnetic dipoles. The direction of spontaneous magnetisation varies from domain to domain.

**32. What is antiferromagnetism?**

In anti-ferromagnetism, electron spin of neighbouring atoms are aligned antiparallel. Anti-ferromagnetic susceptibility is small and positive and it depends greatly on temperature.

**33. State the properties of soft magnetic materials.**

(i) They have high permeability

(ii) They have low coercive force.
(iii) They have low hysteresis loss.

**34. Mention few soft magnetic materials and their applications. Soft magnetic materials:**
(i) Pure or ingot iron
(ii) Cast iron (carbon above 2.5%)
(iii) Carbon steel
**Applications:**
(i) Cast iron used in the structure of electrical machinery and frame work of d.c.machine
(ii) Carbon steel has high mechanical strength used in making motor of turbo alternators.

**35. What are hard magnetic materials?**

Materials which retain their magnetism and are difficult to demagnetize are called hard magnetic materials.

**36. State the properties of hard magnetic materials.**
They possess high value of B-H product
They have high retentivity
They have high coercivity
They have low permeability.

**37. What are ferromagnetic materials?**

Materials which exhibit ferrimagnetism are called ferromagnetic materials. They are also known as ferrites.

**38. What is diamagnetism?**

When a material is placed in a magnetic field, the material becomes magnetized. The direction of the induced dipole moment is opposite to the externally applied magnetic field.

Due to this effect, the material gets very weakly repelled in the magnetic field. This phenomenon is known as diamagnetism.

**39. What are diamagnetic materials?**

The materials which exhibit diamagnetism are called diamagnetic material.

**40. What are the properties of diamagnetic materials?**
(i) Diamagnetic materials repel the magnetic lines of force.
(ii) There is no permanent dipole moment. Therefore, the magnetic effects are very

small.

(iii) The magnetic susceptibility is negative and is independent of temperature and applied magnetic field strength.

**41. What is paramagnetism?**

In certain materials, net magnetic moment is zero though each atom or molecule possesses a permanent magnetic moment in the absence of an external magnetic field.

But when an external magnetic field is applied the magnetic dipoles tend to align themselves in the direction of the magnetic field and the material becomes magnetized. This effect is known as paramagnetism.

**42. What are paramagnetic materials?**

The magnetic materials which exhibit paramagnetism are called paramagnetic material.

**43. What are properties of paramagnetic materials?**

(i) Paramagnetic materials attract the magnetic lines of force.

(ii) They possess permanent dipole moment.

(iii) The susceptibility is positive

**44. What is Giant Magnetoresistance?**

It is a quantum mechanical magneto resistance effect observed in multi layers composed of alternating ferromagnetic and non-magnetic conductive layers.

The effect is observed as a significant change in electrical resistance depending on whether the magnetization of adjacent ferromagnetic layers is in parallel or anti parallel alignment. The overall resistance is relatively low for parallel alignment and relatively high for anti parallel alignment.

**45. Mention application of GMR.**

1. Magnetic field sensors which are used to read data in hard disk drives, biosensors, micro electro mechanical systems (MEMS) and other devices.

2. GMR multilayer structures are also used in magneto resistive random – access memory (MRAM) as cell that store one bit of information.

## PART - B & PART - C

**1.** (i) Classify the magnetic material on the basis of their spin.
(ii) Discuss Weiss theory of ferromagnetism.
(ii) What are its merits and demerits?

**2.** (i) Distinguish between Ferro, Anti-ferro and Ferrimagnetic materials. (*AU June 2010*)

**3.** (i) Explain the origin of ferromagnetism. (*AU May 2011*)
(ii) Discuss the Domain theory of ferromagnetism.

**4.** Distinguish between soft and hard magnetic materials.

**5.** Mention the applications of superconductors.

**6.** Discuss type I and type II superconductors.
**7.** (i) What are high Tc super conductors? Give four examples.
(ii) Explain the following:
Meissner effect, Type I superconductor and principle of magnetic levitation
**8.** (i) What is Superconductivity?
(ii) Mention any four property changes that occur.
(iii) Explain the effect of isotopes on superconductors.
(iv) Explain the Type I and Type II superconductors.
(v) Mention two applications.
**9.** **(**i) Show that perfect diamagnetism and zero resistivity are two essential independent properties of the superconducting state.
(ii) What is Meissner effect?
(iii) Mention two application of superconductivity in medicine.
**10.** Write short notes on
(i) Meissner Effect.
(ii) Type I and Type II superconductors
(iii)High Tc Superconductors
(iv)Applications of Superconductors.
**11.** (i) Write an essay of super conducting materials and its applications.
(ii)Explain the recent developments and applications in super conducting phenomenon.
**12.** Write short notes on
(i) Cryotron (ii) SQUID (iii) MAGLEV
**13.** Explain the various properties of superconductors.

## UNIT – IV SEMICONDUCTOR MATERIALS
## PART – A

**1. What are the p-type and n-type semi conductors? (*AU May 2018*)**

**P-type** semi conductor is the one having holes as the majority charge carriers and electrons as the minority charge carriers.

**Example:** Silicon or Germanium doped with trivalent impurities like Al, Ga and In.

**N-type** semi conductor is the one having electrons as the majority charge carriers and holes as the minority charge carriers.

**Example:** Silicon or Germanium doped with pentavalent impurities like P, As and Sb.

**2. What are donors and acceptors?**

The **donors** are the doped pentavalent impurity atoms like P, As and Sb in Silicon or Germanium donating an electron from its atom to Silicon or Germanium crystal. The **acceptors** are the doped trivalent impurity atoms like Al, Ga and In in Silicon or Germanium accepting an electron from each Silicon or Germanium atom.

**3. Why do we prefer extrinsic semi conductors than intrinsic semi conductors? (*AU June 2012*)**

**Extrinsic semi conductors** have high electrical conductivity which depends on the number of dopant (impurity) atoms and have high operating temperature. But in the **intrinsic semi conductors** the electrical conductivity is very small and is not a constant at different temperatures.

**4. What is the meaning of bandgap of a semi conductor?**

Bandgap (or) energy gap of a semi conductor is the region of energies, which are not allowed to occupy by the electron of that material. Its equal to the energy difference between the minimum energy of conduction band and the maximum energy of valence band of that material. But in a band gap the added impurity atoms can have their energy levels.

**5. Distinguish between direct and indirect bandgap semiconductors.**

In **direct bandgap** semiconductors the electron from the conduction band can directly recombine with the hole in the valence band emitting a light photon and the charge carriers have smaller lifetime. Examples: GaAs, InP. But in **indirect bandgap** semiconductors, the electron from the conduction band can recombine with a hole in the valence band in an indirect manner through the traps. The lifetime of charge carriers is more. Examples: Si, Ge.

**6. What is fermi level in a semiconductor? (*AU May 2016*)**

Fermi level in a semiconductor is the energy level situated in the band gap of the semiconductor. It is exactly located at the middle of the band gap in the case of intrinsic semiconductor. Thus it is a reference energy level from which the maximum energy the valence band and minimum energy of the conduction band are referred. In extrinsic semiconductors, the fermi level is situated in between the acceptor energy level and maximum energy of the valence band in the case of p-type semiconductor and is situated in between the donor energy level and minimum energy of the conduction band in the case of n-type semiconductor.

**7. Discuss the variation of fermi level with temperature in the case of p-type semiconductor or n-type semiconductor.**

The fermi level in extrinsic semiconductor shifts down in the n-type and shifts up in the p-type and reaches the middle of the band gap when the temperature is gradually increased up to 500 K.

**8. Define the operating temperature of a semiconductor.**

The operating temperature of a semiconductor is defined as the maximum temperature up to which extrinsic behavior or amplification is existed. For example, silicon has the operating temperature of 200°C so that the silicon transistors or diodes can be operated safely with effect of doped impurities up to 200°C.

**9. Why do we prefer silicon for transistors and GaAs for laser diodes?**

**Silicon** is an indirect bandgap semiconductor and so the lifetime of the charge carriers are more and hence amplifications are more.

**GaAs** is the direct bandgap semiconductor and the electrons can recombine directly with the holes in the valence band emitting a light photon.

**10. What is Hall Effect? What is its use in the semiconductors? (*AU Dec 2016*)**

Hall Effect is the creation of a transverse e.m.f. across the semiconductor slab carrying current in the perpendicular magnetic field. Using this effect the concentration and the sign of charge can be determined. Further the mobility of charge carriers can also be determined.

**11. What is the effect of doped impurities and increase of temperature in a semiconductor?**

The doped impurities and increase of temperature create the charge carriers and thereby increasing the electrical conductivity of a semiconductor, even though there is an increase of scattering centers. Since the increase of conductivity due to doped impurities and increase of temperature is larger than the reduction of conductivity due to increase of scattering centers.

**12. What is a Hall device?**

The device which uses the Hall Effect for its application is known as Hall device.

**13. What are different types of Hall devices?**

There are three types of Hall devices. They are

(a) Gauss Meter
(b) Electron Multiplier
(c) Electronic Wattmeter.

**14. What are elemental semiconductors? Give some important elemental semiconductors.**

Elemental semiconductors are made from single element of the forth group elements of the periodic table. It is also known as **indirect band gap** semiconductor.

**Example:** Important elemental semiconductors germanium and silicon.

**15.What are the properties of semiconductors?**

(i) They are formed by covalent bond.
(ii) They have empty conduction band.
(iii)They have almost filled valance band.
(iv)These materials have comparatively narrow energy gap.

**16. Mention any four advantages of semiconducting materials.**

(i) It can behave as insulators at 0K and as conductors at high temperature.
(ii) It possess some properties of both conductors and insulators.
(iii) On doping we can produce both N and P-type Semiconductors with charge carriers of electrons and holes respectively.
(iv) It possess many applications in electronic field such as manufacturing of diodes, transistors, LED's,IC etc.

**17. What are compound semiconductors? Give some important compound semiconductors.**

Semiconductors which are formed by combining third and fifth elements or second and sixth group elements in the periodic table are called compound semiconductors.

**Important compound semiconductors are**

| S.No | Group | Compound Semiconductor |
|---|---|---|
| 1. | Combination of third and fifth group elements (III and V) | Gallium Phosphide (GaP)<br>Indium Phosphide (InP)<br>Indium Arsenide (InAs) |
| 2. | Combination of second and sixth group elements (II and VI) | Magnesium Oxide (MgO)<br>Magnesium Silicon<br>(MgSi) Zinc Oxide (ZnO) |

**18. What are the differences between elemental semiconductors and compound semiconductors?**

| S.No | Elemental Semiconductors | Compound Semiconductors |
|---|---|---|
| 1. | They are made of single element Eg: Ge,Si | They are made of compounds Eg: GaAs, GaP, MgO etc |
| 2. | They are called as indirect band gap semiconductors.i.e., electron-hole recombination takes place through traps, which are present in the band gap. | They are called as direct band gap semiconductors. i.e., electron-hole recombination takes place directly with each other. |
| 3. | Here, heat is produced during recombination. | Here, the photos are emitted during recombination. |
| 4. | They are used for the manufacture of diodes and transistors., etc. | They are used for making LED's, laser diodes,IC's etc. |

**19. Define Hall voltage.**

When a conductor (metal or semiconductor) carrying a current (I) is placed in a transverse magnetic field (B),a potential difference (electric field) is produced inside the conductor in a direction normal to the directions of both the current and magnetic field.

This phenomenon is known as **Hall-effect** and the generated voltage is called **Hall-voltage.**

Hall field per unit current density per unit magnetic induction is called **hall coefficient.**

**20. What is a semiconductor?**

Semiconductor is a special class of material which behaves like an insulator at o K and acts conductor at temperature other than 0K. Its resistivity lies in between a conductor and an insulator.

**21. What is an intrinsic semiconductor?**

Semiconductor in an extremely pure form (without impurities) is known as intrinsic semiconductor.

**22. What is an extrinsic semiconductor?**

A semiconducting material in which impurity atoms added (doped) to the material to modify its conductivity is known as extrinsic semiconductor or impurity semiconductor.

**23. What is meant by intrinsic semiconductor and extrinsic semiconductor? What are the differences between intrinsic and extrinsic semiconductor.**

| S.No | Intrinsic Semiconductor | Extrinsic Semiconductor |
|---|---|---|
| 1. | Semiconductor in a pure form is called intrinsic semiconductor. | Semiconductor which are doped with impurity is called extrinsic semiconductor |
| 2. | Here the change carriers are produced only due to thermal agitation. | Here the change carriers are produced due to impurities and may also be produced due to thermal agitation. |
| 3. | They have low electrical conductivity. | They have high electrical conductivity. |
| 4. | They have low operating temperature. | They have high operating temperature. |
| 5. | At 0K, Fermi level exactly lies between conduction band and valence band. | At 0K, Fermi level exactly lies closer to conduction band in "n" type semiconductor and lies near valence band in "p" type semiconductor. |
| | **Examples:** Si,Ge,etc. | **Examples:** Si and Ge doped with Al, In,P,As etc |

**24. What is an n-type semiconductor?**

When a small amount of pentavalent impurity is added to a pure semiconductor, it becomes extrinsic or impure semiconductor and it is known as **n-type semiconductor.**

**25. What is a p-type semiconductor?**

When a small amount of trivalent impurity is added to a pure semiconductor, it becomes extrinsic or impure semiconductor and it is called **p-type semiconductor.**

**26. What is meant by doping and doping agent?**

The technique of adding impurities to a pure semiconductor is known as **doping** and the added impurity is called **doping agent.**

**27. What is meant by donor energy level?**

A pentavalent impurity when doped with an intrinsic semiconductor donates one electron which produces an energy level called **donor energy level.**

**28. What is meant by acceptor energy level?**

A trivalent impurity when doped with an intrinsic semiconductor accepts one electron which produces an energy level called acceptor energy level.

**29. Compare n-type and p-type semiconductors.**

| S.No | N-type semiconductors | P-type semiconductors |
|---|---|---|
| 1. | N-type semiconductor is obtained by doping and intrinsic semiconductor with pentavalent impurity. | P-type semiconductor is obtained by doping and intrinsic semiconductor with trivalent impurity. |
| 2. | Here electrons are majority carriers and holes are minority carriers. | Here holes are majority carriers and electrons are minority carriers |
| 3. | It has donor energy levels very close to CB | It has acceptor energy levels very close to VB. |
| 4. | When the temperature is increased, these semiconductors can easily donate an electron from donor energy level to the CB | When the temperature is increased, these semiconductors can easily accept an electron from VB to donor energy level . |

**30. Define impurity range, exhaustion range and intrinsic range in n-type Semiconductors.**

**Impurity range**: This range is due to the transfer of electrons from the donor energy Level to CB. Here the electron concentration in the CB steadily increases due to ionization of donor atoms.

**Exhaustion range**: When all the electrons are transferred from donor energy level to conduction band, the electron concentration remains constant over certain temperature and is called exhaustion range.

**Intrinsic range:** In this range the n-type semiconductor practically behaves like the Intrinsic semiconductor. Therefore if the temperature is increased the electrons concentration in the conduction band increases rapidly due to the shifting of electrons from valence band to conduction band.

## PART - B & PART - C

1. (i) What are the differences between elemental and compound semiconductors? (*AU Dec 2015*)
   (ii) Discuss the effect of temperature on semiconducting materials.
2. (i) Get an expression for the carrier concentration of an intrinsic semiconductor. (*AU May 2014*)
   (ii) Explain the variation of Fermi energy with temperature in an intrinsic semiconductor.
   (iii) Describe a method of determining the band gap energy of a semiconductor.
3. With a neat sketch explain the variation of Fermi level and carrier concentration with temperature in the case of p-type and n-type semiconductors for low and high doping levels.
4. (i) Assuming Fermi-Dirac statistics and Fermi function derive the expressions for electron and hole densities in an intrinsic semiconductor and hence obtain the expression for their electrical conductivity.
   (ii) Deduce an expression for the energy band gap of an intrinsic semiconductor.
5. (i) What is meant by Hall Effect and Hall co-efficient?
   (iii) Explain how the semiconducting material can be classified into p-type and n-type semiconductors, using Hall co-efficient.
6. (i) Describe an experiment for the measurement of the Hall coefficient. (ii) Write the applications of Hall Effect. (*AU Dec 2016, May 2018*)
7. Explain working of any two Hall devices.

## UNIT – V NANO DEVICES
## PART – A

**1. What is meant by bottom-up approach in constructing Nanomaterials?**

In the "bottom up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. These seek to arrange smaller components into more complex assemblies.

**2. What is meant by top-down approach in constructing Nanomaterials?**

In the "top-down" approach,nano-objects are constructed from larger entities without atomic-level control. These seek to create smaller devices by using larger ones to direct their assembly.

**3. Define nano materials.**

Nanophase materials are newly developed materials with grain size at the nanometer range ($10^{-9}$m) i.e. in the order of 1-100 nm. The particle size in a nano material is 1nm.

**4. Define density of states.**

Electron density is the number of electrons per unit volume in a material. It is determined by using density of states.

**5. Define Fermi energy.**

It is defined as the highest energy level occupied by the electron at 0K in metal.

**6. What is quantum confinement?**

It is process of reduction of the size of the solid such that the energy levels inside become discrete.

**7. What is quantum structure?**

When a bulk material is reduced in its size, atleast one of its dimensions, in the order of few nanometers, then the structure is known as quantum structure.

This phenomenon is known as resonance tunneling.

**8. What is a single electron phenomenon?**

Present day transistors require 10,000 electrons. Rather than moving many electrons through transistors, it may very well be practical and necessary to move electrons one at a time. The phenomena in known as single electron phenomena.

**9. Define Coulomb-Blockade effect.**

The charging effect which blocks the injection or rejection of a single charge into or from a quantum dot is called Coulomb blockade effect.

**10. What is the condition for Coulomb-Blockade effect?**

If two or more charges near one another, they exert coulomb forces upon each other. If two charges are the same kind, the force is repulsive. Therefore, the condition for observing coulomb blockade effects is expressed as

$$W_c = e2/2C >> Kt$$

Where C - capacitance of the quantum dot
T - Temperature of the system
Wc - Charging energy and this is the energy needed to add one negatively Charged Electron to the dot

**11. What is single electron tunneling?**

The Quantization of charge can dominate and tunneling of single electrons across leaky capacitors carries the current. This is called single electron tunneling.

**12. What is a Single Electron Transistor?**

SET is three –terminal switching devices which can transfer electrons from source to drain one by one.

**13. What are the advantages of single electron transistor?**

- The fast information transfer velocity between cells (almost near optic velocity) is carried on via electrostatic interactions only.
- No wire is needed between arrays. The size of reach cell can be as small as 2.5 nm. This made them very suitable for high density memory.
- This can be used for the next generation quantum computer.

**14. What are the limitations of single electron transistor?**

- In order to operate SET circuit at room temperature, the size of the quantum dot should be smaller than 10 nm.
- It is very hard to fabricate by traditional optical lithography and semiconductor process.

- The methods must be developed for connecting the individual structures into logic circuits and these circuits must be arranged into larger 2D patterns.

**15. What are the applications of single electron Transistor?**

- A variety of digital logic function, including AND or NOR gates, is obtained based on SET operating at room temperature.
- It is used for mass data storage.
- IT is used in highly sensitive electrometer.
- SET can be used as a temperature probe, particularly in the range of very low temperatures.
- SET is a suitable measurement set-up for single electron spectroscopy.
- It is used for the fabrication of a homo-dye receiver operating at frequencies between 10 and 300 MHz.

**16. What is quantum interference effect?**

It states that much like waves in classical physics, any two (or more) quantum states can be added together ("superposed") and the result will be another valid quantum state.

**17. What are the applications of quantum interference effect?**

Quantum interference effect is being applied in a growing number of applications, such as the

- Superconducting Quantum Interference Device (SQUID).
- Quantum cryptography
- Quantum computing and quantum interference transistor.

**18. What is spintronics?**

The 'Spin' of the electron can be used rather than its charge to create a remarkable new generation of 'spintronic' devices. These are smaller, more versatile and more robust than those currently making up silicon chips and circuit elements.

**19. What is a carbon nano tube?**

The carbon nano tubes are the wires of pure carbon like rolled sheets of graphite or like soda straws.

**20. What are the types of carbon nano tube structure?**

Three types of nano tube structures are considered by rolling a graphite sheet with different orientations about the axis.

They are (i) Armchair structure
(ii) Zig-zag structure
(iii) Chiral structure

**21. How carbon nano tubes are classified.**

Based on the number of layers, the carbon nano tubes are classified as
(i) Single-walled (SWNTs)
(ii) Multi-walled (MWNTs)
In multi walled nano tubes, more than one CNT are coaxially arranged.

**22. Mention any two properties of carbon nano tubes.**

- Carbon nano tubes are metallic or semiconducting depending on the diameter and chirality (i.e., how the tubes are rolled).
- The energy gap also varies along the tube axis and reaches a minimum value at the tube ends.
- The strength of the carbon-carbon bond is very high therefore any structures based on aligned carbon-carbon bonds will ultimately have high strength.
- One of the important properties of nano tubes is their ability to withstand extreme strain.
- Nano tubes have a high thermal conductivity and the value increased with decrease in diameter.

**23. Write down any two applications of carbon nano tube.**

- The unusual properties of carbon nano tubes have many applications such as battery electrodes, electronic devices and reinforcing fibers for stronger composites etc.
- Carbon nano tubes can be used to make a computer switching device.
- Carbon nano tubes have many applications in battery technology. Lithium which is a charge carrier in some batteries can be stored inside nano tube.
- Carbon nano tube can be used for storing the hydrogen which is used in the development of fuel cells.
- A plastic composite of carbon nano tubes provides light weight shielding material for electromagnetic radiation.
- Nano tunes act as catalysts for some chemical reactions.

**24. Define the term Quantum well and Quantum wire. (*AU May 2018*)**

**Quantum well:** An electrically isolated region, like a thin film, where electrons are constrained in one dimensional and exhibiting quantum behavior is called as a quatum well.

**Quantum wire:** An electrically isolated region, like a nano tube and wire, where electrons are constrained in two dimensional and exhibiting quantum behavior is called as a quatum wire.

## <u>PART - B & PART - C</u>

**1.** Explain quantum confinement and quantum structures in Nano material.
**2.** Discuss density of states in quantum well, quantum wire and quantum dot structure.
**3.** Explain coulomb blockade effect and single electron phenomena.
**4.** Describe construction and working of single electron transistor.
**5.** Discuss on spintronics and also on spin based Field Effect Transistor.
**6.** Describe the carbon nano tubes with properties and applications.

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