EASWARI ENGINEERING COLLEGE

(Autonomous)

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Department of Physics

QUESTION BANK

Subject Code : 231PYS203T **Branches : ECE and RA**

Subject Name : Materials Science for Electronics Engineering

Unit I Electrical and Magnetic Properties of Materials

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 permeated 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 predicted 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. What is fermi energy? What is its importance? (AU Dec 2016)

Fermi energy is the maximum energy of the filled energy stables in a metal at **0 K**. It depends on the free electron density. The properties of metals depend on the value of fermi energy since the effective electrons taking part in various physical phenomena or processes are only the fermi level electrons.

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. 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.

8. 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.

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 scale. This relation is hold 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., $K_{total} = K_{electron} + K_{phonon}$; In metals, $K_{electron} >> K_{phonon}$

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. 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 ms^{-1}). But the drift velocity v_d directional one and is very small (**50** cms^{-1}).

14. 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.

15. 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.

16. 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.

17. 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.

18. 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., **$\rho \propto T^5$**. Above Debye temperature **$\rho \propto T$**.

19. Explain the terms Remanence and Coercivity.

Remanence 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 m^{-1}**.

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

S.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.

21. 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.

22. 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.

23. 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.

24. 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 radio waves.

25. 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.

26. 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.

27. 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

28. 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.

29. 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.

30. What are domains? (AU Dec 2009)

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

31. What is the band theory of Solids?

Band theory of solids is a theoretical model explaining the states of electrons, in solid materials, that can have values of energy only within certain specific ranges.

32. Which are the three important energy bands in solids?

Valence Bands, Conduction bands and forbidden bands are the three important energy bands in solids.

34. 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.

35. Give the meaning of wave function.

The wave function is defined as the probability amplitude of a particle to find its location in the atomic structure and measures the variations of matter waves associated with the particles. It is the complex displacement of the matter waves. Further the probability density is a real quantity and it tells us where the particle is likely to be not where it is. Thus, it connects the particle and its associated wave statistically.

36. What is fermi energy? What is its importance?

Fermi energy is the maximum energy of the filled energy stables in a metal at **0 K**. It depends on the free electron density. The properties of metals depend on the value of fermi energy since the effective electrons taking part in various physical phenomena or processes are only the fermi level electron

37. What are Brillouin zones?

Brillouin zones are the volumes contained in the energy surfaces which indicate the forbidden values of **k** is momentum space. Thus, they are the regions containing the allowed values of **k** in a three-dimensional lattice. Brillouin zones are the geometrical representation of allowed values of k and thus they determine the value of electrical conductivity of a solid

38. Define work function of a metallic surface.

Work function of a metallic surface is defined as the minimum amount of energy imparted to an electron inside the metal so that it just leaves the metal surface

39. Define mean free path.

The mean free path is, particularly in the study of gases, kinetic theory, and statistical mechanics, that describes the average distance a particle (such as a molecule, atom, or photon) travels between successive interactions (collisions) with other particles. It's an important parameter in understanding how gases conduct heat, how sound propagates through gases, and various other phenomena.

40. State Fermi distribution function.

The Fermi-Dirac distribution function is a fundamental equation in quantum statistics that describes the probability of an energy state being occupied by a fermion (such as an electron) at a given temperature. Fermions follow the Pauli exclusion principle, which means that no two fermions can occupy the same quantum state simultaneously. This distribution is crucial for understanding the behavior of electrons in solids, especially in metals and semiconductors

41. Define magnetic susceptibility and magnetic permeability.

Magnetic susceptibility: It is a measure of how easily a material can be magnetized in the presence of an external magnetic field. It quantifies the extent to which a material becomes magnetized when subjected to a magnetic field.

Magnetic permeability: It is a property of a material that describes its ability to support the formation of a magnetic field within itself. It is a measure of the material's ability to conduct magnetic flux and is defined as the ratio of the magnetic flux density to the magnetic field intensity.

42. Define hysteresis

Hysteresis refers to the phenomenon where the response of a system lags behind its input. In the context of magnetism, it describes the lagging of the magnetic induction (**B**) in a material behind the external magnetic field (**H**) that produces it. This lagging effect is due to the alignment and realignment of magnetic domains within the material as the external magnetic field changes, causing energy loss and resulting in a characteristic loop-shaped magnetization curve when plotted against the changing magnetic field.

43. Define curie temperature

The Curie temperature (**Tc**) is the temperature at which certain materials undergo a phase transition from a ferromagnetic or ferrimagnetic state to a paramagnetic state. Above the Curie temperature, these materials lose their permanent magnetization and become more randomly oriented in terms of their magnetic moments. Below the Curie temperature, these materials exhibit spontaneous magnetization and strong magnetic properties.

44. Define Bohr magnetron

It is a physical constant denoted by **μ_B**. It represents the magnetic moment of an electron due to its orbital motion around the nucleus in the Bohr model of the atom. Mathematically, it is defined as the product of the electron's charge (e) and its reduced Planck constant (ħ) divided by twice the electron's mass (me), i.e., **$\mu_B = e\hbar / (2m_e)$**. It is approximately equal to **9.274×10^{-24} Joule Tesla^{-1}**. The Bohr magneton provides a fundamental unit of magnetic moment for individual electrons in the context of quantum mechanics.

45. What are electronic devices?

Electronic semiconductors are materials that have electrical conductivity between that of a conductor and an insulator. They are key components in electronic devices like transistors, diodes, and integrated circuits. Semiconductor materials, like silicon and germanium, are widely used due to their ability to control and manipulate the flow of electric current.

46. What are Non-Linear Optical Materials?

Non-linear optical materials generate new frequencies of light when exposed to intense electromagnetic radiation, used in fields like telecommunications and laser technology for applications such as frequency conversion.

47. Define Hall Effect and Hall Voltage

The Hall Effect refers to the generation of a voltage perpendicular to the flow of an electric current in a conductor, due to the presence of a magnetic field. This phenomenon is called the Hall Voltage, and it's proportional to the strength of the magnetic field, the current, and a characteristic of the material called the Hall coefficient.

48. What are Extrinsic Semiconductors?

Extrinsic semiconductors are materials intentionally doped with impurities to modify their electrical properties, enhancing conductivity. This controlled doping process allows for tailored semiconductor behavior in electronic devices.

49. What are Liquid Crystals?

Liquid crystals are a state of matter that exhibits properties of both liquids and solids. They flow like liquids but have some degree of order like solids. They are commonly found in electronic displays like LCD screens, where their ability to change orientation in response to an electric field is utilized to control the passage of light, enabling the display to create images.

50. What is the principle of GMR?

The fundamental principle of the GMR effect is based on electron spins. In a magneto-resistor, electron scattering rates increase or decrease as a function of the interaction of the spin state of the electrons and the magnetic orientation of the medium in which the electrons are traveling.

PART – B

1. 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, May 2023)**

2. Derive an expression for electrical conductivity in a material in terms of mobility of electrons. How does the conductivity vary with temperature?

3. (i) Derive an expression for density of states. **(AU Dec 2016)**

(ii) State the merits and demerits of classical free electron theory.

4. (i) Define Fermi energy.

(i) Obtain a general expression for the Fermi energy of electrons in solids at **0 K**.

5. (i) Define Fermi energy.

(ii) Explain Fermi Dirac distribution for electrons in a metal.

6. Derive an expression for the density of states and based on that calculate the carrier concentration in metals. **(AU May 2017, May 2023)**

7. Write short notes on (i) Energy levels (ii) Energy bands (iii) Bound and free electrons (iv) Electronic work function.

8. (i) What is Ferromagnetism?

(ii) Explain the reason for the formation of domain structure in a ferromagnetic material and how the hysteresis curve is explained on the basis of the domain theory? **(AU Dec 2009, MAY 2023)**

9. (i) Classify the magnetic material on the basis of their spin.

(ii) Discuss Weiss theory of ferromagnetism.

(iii) What are its merits and demerits? What is the energy loss/per cycle?

10. Distinguish between Dia, Para and Ferro magnetic materials. **(AU June 2010, MAY 2022)**

11. Distinguish between soft and hard magnetic materials.

12. Define density of states. Derive an expression for the density of states in a cubical Metal.

13. Write a short note on

(i) Electrons in a periodic potential.

(ii) Tight binding approximation in solids.

14. Derive an expression for the effective mass of an electron and concept of hole.

15. Explain the properties of Dia, Para and Ferro magnetic materials.

16. Explain Para magnetism in conduction electrons in metals.

17. Discuss the origin and exchange interaction of ferromagnetism.

18. Describe about quantum interference devices.

19. Distinguish between hard and soft magnetic materials.

20. What are GMR devices? explain its working.

21. A metallic wire has a resistivity of **1.42×10^{-8} Ω m**. For an electric field of **0.14 V/m**. Find,

(i) Average drift velocity

(ii) Mean collision time assuming, there are 6 x 1028 electrons /m3

22. Find the drift velocity of the free electrons in a copper wire whose cross-sectional area is **1.0 mm^2** when the wire carries a current of 1A Assume that each copper atom contributes one electron to the electron gas. Give **$n = 8.5 \times 10^{28}\ m^{-3}$**.

23. Find the relaxation time of conduction electrons in a metal of resistivity **1.54×10^{28} Ωm**, if the metal has the conduction electrons **$5.8 \times 10^{28}\ m^{-3}$**.

PART – A

1. **What are p— type and n— type semiconductors? (*AU May 2018*)**

   p- type: semiconductor 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: semiconductor 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 semiconductors than intrinsic semiconductors? (*AU June 2012*)**

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

4. **What is the meaning of bandgap of a semiconductor?**

   Bandgap (or) energy gap of a semiconductor 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** and **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. Define diffusion current.

Non-uniform distribution of charge carriers creates the regions of uneven concentrations in the semiconductor.

The charge carriers move from the regions of higher concentration to the regions of lower concentration. This process is known as diffusion. The current is known as diffusion current.

13. Write down the Einstein's relation.

The relation between the mobility (μ) and diffusion coefficient (D) of a semiconductor is known as Einstein's relation

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T = \frac{kT}{q} = \frac{T}{11{,}600}$$

Where, **D_n** -Diffusion coefficient of electron; Dp -Diffusion coefficient of holes; **μ_n** -Mobility of electron; **μ_p** -Mobility of holes; **V_T** -Temperature equivalent.

14. What is a Hall device?

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

15. 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.

16. What is Breakdown voltage is p-n junction?

The reverse voltage at which the **p-n** junction breaks down with sudden rise in reverse current is called breakdown voltage.

17. What is Zener breakdown?

In a heavily doped junction diode, breaking of covalent bonds occurs due to increase in reverse voltage which leads to junction breakdown. It is called Zener breakdown.

18. What is avalanche breakdown?

In lightly doped junction diodes, at a relatively high reverse voltage breaking of covalent bond occurs due to collision of accelerated electrons with valence electrons. The multiplication of collision leads avalanche effect. Thus, the junction breakdown occurs. It is known avalanche breakdown.

19. What are the differences between Zener and avalanche breakdown?

S.No	Zener breakdown	Avalanche breakdown
1.	It occurs in a heavily doped junction.	It occurs in a lightly doped junction.
2.	It occurs with reverse bias voltage less than **6V**.	It occurs in PN junction diode with reverse voltage greater than **6V.**
3.	The reverse bias of VI characteristics is very sharp in breakdown region.	The reverse bias of VI characteristics is not sharp. (i.e., soft)
4.	It occurs by breaking covalent bonds due to very high electrical field developed by the reverse bias.	It occurs by breaking covalent bonds due to collision of accelerated electrons as a chain reaction.
5.	The breakdown voltage decreases if the junction temperature increases.	The breakdown voltage increases if the junction temperature increases.

20. What is Schottky diode?

It is junction formed between a metal and n-type semiconductor. When the metal has a higher work function than that of n-type semiconductor then the junction formed is called Schottky diode.

21. What are advantages of Schottky diodes?

- In Schottky diode, stored charges or depletion region is negligible. So a Schottky diode has a very low capacitance.
- In Schottky diode, the depleting region is negligible. So, the Schottky diode will immediately switch from **ON** to **OFF** state (fast recovery time).
- The depletion region is negligible in Schottky diode. So applying a small voltage is enough to produce large current.
- IT has high efficiency.
- It operates at high frequencies.
- It produces less noise.

22. What are the applications of Schottky diode?

- Schottky diode can be used for rectification of singles of frequencies even exceeding **300 MHz.**
- It is commonly used in switching device at frequencies of **20 GHz**.
- It is used in radio frequency (RF) applications.
- It is widely used in power supplies.

23. What are the differences between Schottky diode and p-n diode?

S.No	Schottky Diode	P-N Diode
1.	Forward current due to thermionic emission (majority carrier transport).	Forward current due to diffusion currents (Majority carrier transport).
2.	Reverse current only due to majority carriers that overcome the barrier (less temperature dependent).	Reverse current due to minority carriers diffusing to the depletion layer and drifting to the other side (strong temperature dependence).
3.	Cut-in voltage is small (about **0.3 V**).	Cut-in voltage is large (about **0.7 V**).
4.	High switching speed, because of majority carries transport. No recombination time needed.	Switching speed limited by the recombination time of the injected minority carriers.

24. What is Ohmic contact?

An ohmic contact is a type of metal semiconductor junction. It is formed by a contact of a metal with a heavily doped semiconductor. When the semiconductor has a higher work function than that of metal, then the junction formed is called the Ohmic junction.

25. What are the uses of Ohmic contact?

The use of ohmic contacts is to connect one semiconductor device to another, an IC, or to connect an IC to its external terminals.

26. What are the differences between Schottky diode and Ohmic contacts?
(AU May 2018)

S.No	Schottky Diode	Ohmic contact
1.	It acts as a rectifier	It acts as a resistor
2.	Very low forward resistance but very high reverse biased resistance	Resistance is same in both forward and reverse bias
3.	Work function of metal is greater than that of semiconductor $\varphi_m > \varphi_{semi}$	Work function of metal is smaller than that of semiconductor $\varphi_m < \varphi_{semi}$

27. What is a tunnel diode?

A tunnel diode is a simple p-n junction in which both p and n sides are very heavily doped with impurities. It is a p-n junction which exhibits negative resistance between two values of forward voltage (i.e., between peak-point voltage and valley point voltage).

28. What are the advantages of tunnel diodes?

- Tunnel diode has low noise.
- It is easy to operate this diode.
- The switching speed is high.
- It consumes low power.

29. What are the disadvantages of tunnel diodes?

- Voltage range over which it can be operated is **1 V** or **less**
- For a two-terminal device, there is no isolation between the input and output circuit

30. What are the applications of tunnel diodes?

- Tunnel diode is used as ultra high-speed switch with switching speed of the order of nano second (ns) or Pico second (ps)
- It is used in logic memory storage device.
- It is used in microwave oscillator
- It can be used in relaxation oscillator circuit

31. What are the differences between tunnel diode and p-n junction diode?

S.No	Tunnel Diode	pn Junction Diode
1.	Doping levels at **p** and **n** sides are very high.	Doping in both **p** and **n** sides is normal.
2.	**Majority carriers current** responds much faster to voltage changes -suitable to microwaves.	Majority carrier current does not respond so fast to voltage changes-suitable for low frequency applications only.
3.	Shows negative resistance characteristics –useful for oscillators.	Does not show negative resistance – used as detector and rectifiers.
4.	Preferred semiconductors are **Ge** and **GaAs**	Preferred semiconductors are **Ge** and **Si**.
5.	It is a low noise device.	Moderate noise characteristics.

32. What is metal oxide semiconductor capacitor?

Metal oxide semiconductors (**MOS**) are used as capacitors.

33. What are the applications of metal oxide semiconductor capacitor?

These types of capacitors are widely used as internal capacitors in Integrated circuits (IC's).

34. What are power transistors?

Transistors which handle high voltage and high current ratings are known as power transistors.

35. What are the advantages and disadvantages of power transistor?

Advantages

- The power loss is low
- The switching speed is high.
- The size of this transistor is large.
- It can handle high power with high efficiently.
- Its thermal resistance is low.

Disadvantages

- It has little ability to withstand a reverse voltage.

36. What are the applications of power transistors?

- It is used in power switching devices.
- It is also used in power amplifiers.

PART – B

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, MAY 2022,2023**)

   (ii) Explain the variation of Fermi energy with temperature in an intrinsic semiconductor.

3. With a neat sketch explain the variation of carrier concentration and the electrical conductivity with temperature. Write a note on hole concentration in an extrinsic semiconductor.

4. (i) What is meant by **Hall Effect** and **Hall co-efficient**?

   (ii) Explain how the semiconducting material can be classified into p-type and n-type semiconductors, using Hall co-efficient. (**May 2022**)

5. (i) Describe an experiment for the measurement of the Hall coefficient.

   (ii) Write the applications of Hall Effect. (**AU Dec 2016, May 2018**)

6. Write down expression for drift current and diffusion currents. Derive Einstein's relation.

7. Explain working of any two Hall devices.

8. Explain Zener and avalanche breakdown in p-n junction.

9. Describe construction and working of Schottky diode.

10. Write a note on ohmic contact.

11. Describe the construction and working of tunnel diode.

12. Explain principle and working metal oxide semiconductor capacitor.

13. Describe the construction and working of power transistor.

PART - A

1. **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.

2. **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.

3. **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 $E_i = E + P/3\epsilon_0$ for simple elements dielectrics.

   Here, **E** -applied field strength and **P** -polarization field produced in the dielectric.

4. **Define dielectric loss. (*AU June 2010*)**

   When a dielectric is subjected to the 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. The dielectric loss is mainly due to imaginary term of the complex dielectric constant.

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

   Dielectric constant is the measure of the polarization in a material. It is also called relative permitivity ε_r of the material.

   $$\varepsilon_r = \frac{\varepsilon_m}{\varepsilon_O}$$

   Where, ε_m -permittivity of the medium; ε_o -permittivity of the free space.

6. **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.

7. **Define dielectric strength. (AU June 2012 MAY 2023)**

   Dielectric strength is the minimum voltage required per unit thickness of the material to produce dielectric breakdown or dielectric failure. **Unit: Vm^{-1}**

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

   Ferro electricity: Property by which dielectric materials exhibit electric polarization even in the absence of applied electric field.

   Piezo electricity: Property by which electric polarization is produced by mechanical pressure.

   Pyroelectricity: Property by which electric polarization is produced by thermal energy.

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

   i. Transformer oil
   ii. Askarels
   iii. Silicon liquid

10. What is dielectric polarization?

Dielectric polarization is the alignment of electric dipoles within a dielectric material in response to an external electric field.

11. Define electric dipole moment.

Electric dipole moment is a measure of the separation of positive and negative charges within a system, represented by the product of the magnitude of the charges and the distance between them.

12. How does dielectric polarization affect the electric field within a capacitor?

Dielectric polarization reduces the effective electric field within a capacitor, resulting in an increase in capacitance.

13. Explain the concept of induced polarization in dielectric materials.

Induced polarization refers to the polarization of a dielectric material in response to an external electric field, leading to the alignment of electric dipoles within the material.

14. What is the relationship between dielectric constant and polarization in a dielectric material?

The dielectric constant, also known as relative permittivity, is a measure of a material's ability to store electrical energy in an electric field. It is directly proportional to the degree of polarization induced in the material.

15. How does temperature affect dielectric polarization?

Generally, an increase in temperature reduces the degree of dielectric polarization in a material due to increased thermal motion of atoms or molecules, which disrupts the alignment of electric dipoles.

16. Explain the significance of dielectric polarization in capacitor applications.

Dielectric polarization is crucial in capacitor applications as it increases the capacitance of the capacitor, allowing it to store more charge for a given voltage.

17. Differentiate between electronic and ionic polarization in dielectric materials.

Electronic polarization occurs due to the displacement of electrons within atoms or mol^{1}1ecules, while ionic polarization arises from the displacement of ions in the crystal lattice of a material.

18. How does dielectric polarization influence the energy stored in a capacitor?

Dielectric polarization increases the energy stored in a capacitor by reducing the electric field strength within the capacitor, thereby allowing it to hold more charge for a given voltage.

19. Discuss the role of dielectric polarization in preventing electrical breakdown in insulating materials.

Dielectric polarization helps to increase the breakdown voltage of insulating materials by reducing the electric field strength at the material's surface, thus inhibiting the formation of electric arcs and breakdown.

20. What is relative permittivity?

Relative permittivity, also known as dielectric constant, is the ratio of the permittivity of a substance to the permittivity of free space.

21. What is the symbol used to represent relative permittivity?

The symbol used to represent relative permittivity is $\boldsymbol{\varepsilon_r}$ or sometimes simply $\boldsymbol{\varepsilon}$.

22. What is the relative permittivity of a vacuum or free space?

The relative permittivity of vacuum or free space is exactly **1**.

23. How does relative permittivity affect the capacitance of a capacitor?

The capacitance of a capacitor is directly proportional to the relative permittivity of the dielectric material between its plates.

24. State the formula to calculate the capacitance of a capacitor with a dielectric material.

The formula to calculate the capacitance (**C**) of a capacitor with a dielectric material is:

$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon_r \varepsilon_O}{d}$$

where ε_r is the relative permittivity, ε_O is the permittivity of free space, A is the area of the plates, and d is the distance between them.

25. What happens to the capacitance of a capacitor when a dielectric material with a high relative permittivity is inserted between its plates?

The capacitance of the capacitor increases.

26. Name a material with a high relative permittivity commonly used as a dielectric in capacitors.

One example of a material with a high relative permittivity commonly used as a dielectric in capacitors is ceramic.

27. What is the physical significance of relative permittivity in materials?

Relative permittivity indicates how much a material can be polarized by an applied electric field, affecting its ability to store electrical energy.

28. How does relative permittivity vary with temperature in most materials?

In most materials, the relative permittivity decreases with increasing temperature.

29. Explain why air is often used as a dielectric material in capacitors.

Air is often used as a dielectric material in capacitors because it has a relatively low relative permittivity (**$\varepsilon_r \approx 1$**), which allows for a higher capacitance compared to materials with higher relative permittivity. Additionally, air is readily available and inexpensive.

30. Why is it called a dipole moment?

A dipole moment is a measurement of the separation of two opposite electrical charges. Dipole moments are a vector quantity. The magnitude is equal to the charge multiplied by the distance between the charges and the direction is from negative charge to positive charge: **$\mu = q \cdot r$**

where μ is the dipole moment, q is the magnitude of the separated charge, and r is the distance between the charges.

31. How do you find the largest dipole moment?

When there is a difference in the electronegativity of two atoms involved in a bond, a dipole moment happens. The larger the electronegativity difference between the two atoms, the larger the bond's dipole moment and polarity.

32. What is the symbol of dipole moment?

The dipole moment (**μ**) is the calculation of the net molecular polarity at either end of the molecular dipole, which is the magnitude of the charge **Q** times the distance **r** between the charges. Dipole moment talks about the charge separation in a molecule.

33. Why all insulators are dielectric to some degree?

All non-conducting materials are capable of electronic polarization, which is why all insulators are dielectric to some degree.

34. What is polarization vector?

Polarization vector (P) measures the extent of polarization in a unit volume of dielectric matter. It is the vector sum of dielectric dipoles per unit volume.

35. When is an atom said to be polarized?

An atom is said to be polarized if it possesses an effective dipole moment, that is, if there is a separation between the centers of negative and positive charge distribution

36. What is the SI unit of polarisation?

The SI unit of polarization is **Cm^{-2}**. Generally, the area is very small so it can be taken as **Ccm^{-2}.**

37. Define Polarization Mechanism

Polarization mechanism refers to the process by which electromagnetic waves oscillate in a particular direction, leading to the alignment of their electric field vectors. This alignment occurs perpendicular to the direction of wave propagation, resulting in a specific orientation of the wave's electric field.

38. Name some types of polarization mechanisms

i. Interfacial polarization

ii) Ionic polarization

iii) Total polarization

iv) Dipolar polarization

39. Express Dipole Moment in terms of Polarization Vector

The dipole moment (**μ**) of a system is given by the product of the magnitude of the polarization vector (**P**) and the volume of the system (**V**), i.e., **$\mu = P \times V$**.

40. Mention two important properties of an insulating material.

1.It should have high insulation resistance.

2. It should have high dielectric strength to withstand very high voltage without any break down.

41. What are the various sources by which power loss occurs in a dielectric?

1. High voltage
2. High frequency
3. Aging
4. High temperature and
5. Moisture.

42. What is the effect of frequency of a.c. electric field on polarization?

As the frequency increases, the total polarization in the material decreases. In a.c electric field all polarization processes occur. But at high frequency electric fields (optical frequencies) space charge polarization and orientational polarization do not occur.

43. Which category of polarizability strongly depends on temperature and frequency?

Ionic Polarization is significantly influenced by both temperature and frequency.

44. What is the frequency range for electronic polarization in the electromagnetic spectrum?

Electronic polarization typically occurs in the ultraviolet region of the electromagnetic spectrum.

45. What is the specific rotation of a 10% sugar solution that rotates the plane of polarization by 13.2°?

The specific rotation of the sugar solution is approximately **44°**.

46. What is the Clausius-Mossotti equation?

The **Clausius-Mossotti** equation expresses the relation between the dielectric constant (ϵ_r) of a material and the atomic polarizability (α) of its constituent atoms or molecules.

47. Define Electrolytic capacitors.

An electrolytic capacitor is a capacitor that uses an oxide film made of aluminum, tantalum or other oxidizable metal as a dielectric. Because of its potential for large capacitance, this type of capacitor is used extensively in power supply circuits and similar applications.

48. What is Supercapacitor?

A supercapacitor, also called an ultracapacitor, is a high-capacity capacitor, with a capacitance value much higher than solid-state capacitors but with lower voltage limits. It bridges the gap between electrolytic capacitors and rechargeable batteries.

49. What is EDLC?

Electric double layer capacitor (**EDLC**) is the electric energy storage system based on charge–discharge process (**electrosorption**) in an electric double layer on porous electrodes, which are used as memory back-up devices because of their high cycle efficiencies and their long life-cycles.

50. What is dielectric breakdown?

Dielectric breakdown is the sudden failure of an insulating material when exposed to an electric field surpassing its dielectric strength, leading to the loss of insulation and potential damage.

51. Define dielectric strength.

Dielectric strength is the maximum electric field a material can withstand without undergoing breakdown. It measures the insulation capability of the material.

52. Define dielectric loss.

Dielectric loss is the energy dissipated as heat when a dielectric material is subjected to an alternating electric field. It's characterized by the loss tangent, representing the ratio of dielectric loss to stored energy.

53. What is dielectric constant?

Dielectric constant, or relative permittivity, measures a material's ability to store electrical energy in an electric field. It's the ratio of the electric field strength in a material to that in a vacuum. High values indicate increased capacitance in electronic devices.

PART- B

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, MAY 2023**)

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. Explain the application of dielectric materials in capacitor & transformer. (**AU June 2010**)

6. Write short notes on ferroelectricity and its application.

7. Describe the different types of polarization.

8. Define electric and ionic polarization and explain them with a neat diagram.

9. Discuss the different types of polarization mechanisms and polarizability involved in dielectric material.

10. Derive **Clausius -Mosotti** equation. Explain with the help of a neat sketch the frequency and temperature dependence of dielectric properties?

11. Define dielectric breakdown. Explain five types of dielectric breakdown that occur in dielectric materials.

12. Define the following terms (i) Dielectric Polarization, (ii) Polarisability, (iii) Dielectric Constant, (iv)Spontaneous polarization, (v) Electric susceptibility.

13. What are requirements of good insulating materials?

14. Compare active and passive dielectrics.

15. What are the differences between polar and nonpolar molecules?

16. What is chemical and electrochemical breakdown?

17. What is meant by dielectric loss? Explain the phenomena of dielectric loss in detail?

18. (i) What is ferroelectricity?

    (ii) Explain the hysteresis curve exhibited by a ferroelectric material with a suitable sketch.

    (iii) Give examples for ferroelectric material.

Unit IV **Optical Properties of Materials**

PART – A

1. **Comment on the blue color of the sky. (May 2019)**

   The molecules of air and other fine particles in the atmosphere have a size smaller than the wavelength of visible light. Thus, they are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end. Red light has a wavelength greater than blue light. Thus, when sunlight passes through the atmosphere, the fine particles in air scatter blue color (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes.

2. **Why organic LED is called so? (May 2019)**

   An organic light-emitting diode (**OLED** or **Organic LED**), also known as an organic EL (organic electroluminescent) diode, is a light-emitting diode (**LED**) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current

3. **Discuss absorption of light by semiconductors. (May 2018)**

   Light normally incident on a solid will be partially reflected at the air (or vacuum) and solid interface, and the remaining light will enter the solid. If it is absorbed by the solid, its intensity will decrease exponentially with distance as $e^{(-a(\lambda)\chi)}$, where $a(\lambda)$ is the absorption coefficient.

4. **What are the optical properties? (May 2018)**

   Absorbance, Birefringence, Luminosity

5. **What are optical materials?**

   The materials which are sensitive to light are known as Optical materials. These optical materials exhibit a variety of optical properties.

6. **What are the types of optical materials?**

   Generally, optical materials are classified into three types based on the nature of propagation of light namely,

   (i) Transparent (ii) Translucent (iii) Opaque

7. **Define Scattering of light.**

   It is a process by which the intensity of the wave attenuates as it travels through a medium.

8. **Define carrier generation and recombination.**

   The carrier generation is the process whereby electrons and holes are created. The recombination is the process whereby electrons and holes are annihilated.

9. **What are types of carrier generation?**

   (i) Photo generation

   (ii) Phonon generation

   (iii) Impact ionization

10. **What are types of recombination process?**

    (i) Radiative Recombination

    (ii) Shockley-Read-Hall Recombination

    (iii) Auger Recombination

11. What is exciton?

The combination of an electron in an excited state (below conduction band) and the associated hole in valence band (electron-hole pair) is known as an exciton.

12. What are the types of excitons?

Types of excitons

(i) **Frenkel excitons** -Strongly (tightly) bound excitons

(ii) **Mott and Wannier excitons** – Weakly bound excitons

13. What are the types of photo detector?

There are three types of Photo-detectors

(i) Photo emissive (ii) Photo conductive (iii) Photo voltaic

14. What is a Photo conductor?

The simplest solid – state photo detector is a piece of photo conducting semiconductor. It is also called a photo resistive device.

It is based on the decrease in the resistance of certain semiconductors when they are exposed to light radiation (both infrared and visible). Such materials have a high dark resistance and low resistance on irradiation.

15. What is a photo-voltaic device?

Semiconductor junction photo diodes are called photo-voltaic devices.

16. What are types of photo-voltaic devices?

There are three Photo–voltaic devices.

(i) pn Junction photo detector (ii) PIN photo diode (iii) Avalanche photo Diode (**APD**)

17. What is LED?

It is a p-n junction diode which emits light when it is forward biased.

18. What is the basic principle be hold LED?

The injection of electrons into the **p -region** from **n -region** makes a direct transition from the conduction band to valence band. Then, the electrons recombine with holes and emit photons of energy E_g. The forbidden gap energy is given by,

$$E = h\nu = \frac{hc}{\lambda}$$

19. What are the advantages of LEDs? (Jan 2006)

- LEDs are smaller in size. A number of LEDs can be stacked together in a small space to form numerical display.
- LEDs can be turned ON and OFF in less than 1 nano second (10^{-9} s). So, they are known as fast devices.
- Varieties of LEDs are available which emit light in different colors like red, green, yellow etc.
- Light modulation can be achieved with pulse supply.
- It has long life time.
- It has low drive voltage and low noise.
- It is easily interfaced to digital logic circuits.
- It can be operated over a wide range of temperatures.

20. What are the disadvantages of LEDs?

- They require high power.
- Their preparation cost is high when compared to LCD.

21. What are the applications uses of LEDs?

Because of their miniature size, they are widely used in numeric and alphanumeric display devices.

- They are used as indicator lamps.
- They are used as light sources in fiber-optic communication system.
- Infrared LEDs are used in burglar alarms.
- They are used in image sensing circuits used for picture phone.

22. What is a laser diode?

It is a specially fabricated p-n junction diode. This diode emits laser light when it is forward biased.

23. What are the advantages of Laser diodes?

- This laser is very small in size and compact.
- It has high efficiency.
- The laser output can be easily increased by increasing the junction current.
- It is operated with less power than ruby and CO_2 lasers.
- It requires very little additional equipment.
- It emits a continuous wave output or pulsed output.
- It emits a continuous wave output or pulsed output.

24. What are the applications of Laser diodes?

- Used in fiber optic communication.
- Used in various measuring devices such as range finders, bar-code readers.
- Used in printing industry both as light sources for scanning images and for resolution printing plate manufacturing.
- Infrared and red laser diodes are common in CD players, CD-ROM and DVD technology. Violet lasers are used in HE-DVD and Blue –ray technology.
- High power laser diodes are used in industrial applications such as heat treating, cladding seam welding and for pumping other lasers.
- Used in laser medicine especially, dentistry.

25. What are organic light emitting diodes?

Organic light emitting diodes (OLEDs) are solid state devices made up of thin films of organic molecules that produce light with the applications of electricity.

26. What are drawbacks of OLED?

- The biggest technical problem for OLEDs is the limited lifetime of the organic materials.
- The intrusion of water into displays can damage or destroy the organic materials.
- Color- The reliability of the OLED is still not up to the mark. After a month of use the screen becomes non-uniform.

27. What are advantages of OLED?

- OLEDs are tough enough to use in portable devices such as cellular phones digital video cameras, DVD players, car audio equipment etc.,
- Can be viewed up to **160 degrees**.
- High information applications including videos and graphics (Active matrix)
- OLEDs are **paper-thin**.
- Up to **20% to 50% cheaper** than LCD processes.
- They hold the ability to handle streamlined video, which could revolutionize the display and cellular phone market.
- Consumes **less power**.

28. What are the applications of OLED?

- **OLED** technology is used in commercial applications such as small screens for mobile phones and portable digital audio players (MP3 players), car radios, digital cameras and high- resolution micro displays for head-mounted displays.
- They can be used in television screens, computer displays, advertising information and indication.
- **OLED**s can also be used in light sources for general space illumination and large-area light-emitting elements.

29. Why organic LED is called so?

An organic light-emitting diode (**OLED** or **Organic LED**), also known as an organic **EL** (organic electroluminescent) diode, is a light-emitting diode (**LED**) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current.

30. Mention any four required properties of light sources used in the optical communication.

- It must emit the required wavelength **1.3 μm** and **1.55 μm**.
- To avoid dispersion, the spectral width of the source should be very small (**1nm**).
- It should be possible to modulate the source at high speeds(**>Gb/s**).
- It should have compact size and be possible to design in the integrated form.

31. Discuss absorption of light by semiconductors.

Light normally incident on a solid will be partially reflected at the air (or vacuum) and solid interface, and the remaining light will enter the solid. If it is absorbed by the solid, its intensity will decrease exponentially with distance as **$\exp(-a(\lambda)\chi)$,** where **$a(\lambda)$** is the absorption coefficient.

32. What are the optical properties?

Absorbance: How strongly a chemical attenuates light.

Birefringence: It is the optical property of a material having a refractive index that depends on the polarization and propagation direction of light.

Luminosity: It is the amount of electromagnetic energy a body radiates per unit time. It is mostly measured in two forms i) **Visual** (visible light only) ii) **Bolometric** (Total radiant energy)

Photosensitivity: It is the amount to which an object reacts upon receiving photons, especially visible light.

33. What are optical materials?

The materials which are sensitive to light are known as Optical materials. These optical materials exhibit a variety of optical properties.

34. What are the laser light properties? How are they produced?

- Higher monochromaticity
- High intensity
- High coherence
- High directionality

The above-mentioned properties are attained by stimulated emissions.

35. Why laser emission is not obtained in an atomic system under thermal equilibrium?

Under thermal equilibrium, the probability for spontaneous emission is far greater than the probability of stimulated emission. Therefore, laser emission is not possible. Laser emission can be obtained when there is nonthermal equilibrium i.e., by getting population inversion through pumping the matter.

36. What is meant by laser action? What are the conditions to achieve it?

Laser action means the amplification of light by stimulated emission of radiation. To get laser action there should be population inversion and stimulated emission should take place.

37. What is meant by threshold condition for laser oscillation?

There should be a minimum amount of population inversion from which laser oscillation starts. This is called threshold condition for laser oscillations. Therefore, to start the laser oscillation, the gain coefficient should exceed the threshold value.

38. What are the types of optical materials?

Generally, optical materials are classified into three types based on the nature of propagation of light namely,

(i) Transparent (ii) Translucent (iii) Opaque

39. Define Scattering of light.

It is a process by which the intensity of the wave attenuates as it travels through a medium.

40. Define carrier generation and recombination.

The carrier generation is the process whereby electrons and holes are created. The recombination is the process whereby electrons and holes are annihilated.

41. What are types of carrier generation?

(i) Photo generation

(ii) Phonon generation

(iii) Impact ionization

42. What are types of recombination process?

(i) Radiative Recombination

(ii) Shockley-Read-Hall Recombination

(iii) Auger Recombination

43. Mention the important semiconductors used in laser and LEDs.

- **InGaAsP**- To produce the wavelength **1.3 μm** to **1.7 μm**.
- **InGaAlAs**- To produce wavelength from **0.8 μm** to **0.9 μm**.

44. What are the drawbacks of homojunction laser diodes?

- Threshold current is very large.
- The output beam has large divergence.
- Coherence and stability are poor.
- Optical confinement is very poor.

45. Why to prefer laser diodes over LEDs for communication applications?

- Longer lifetime
- Higher modulation rates
- Very narrow spectral width of the source
- High optical power output
- Efficient waveguide structure

46. How does LED work?

Due to higher population of injected minority carrier, there is enormous radiative recombination when there is forward bias across the active layer of LED.

47. What is exciton?

The combination of an electron in an excited state (below conduction band) and the associated hole in valence band (electron-hole pair) is known as an exciton.

48. What are the types of excitons?

Types of excitons:

(i) **Frenkel excitons** -Strongly (tightly) bound excitons.

(ii) **Mott and Wannier excitons** – Weakly bound excitons

49. Give the importance of excitons.

- The excitons play an important role in the luminescence of solids.
- Excitons are unstable and they will separate at high temperature.
- The exciton can move through the semiconductor and transport energy.
- The excitons do not transport any charge as it is electrically neutral.

50. What is photo diode?

It is a reverse biased p—n junction diode which responds to light absorption.

51. What are the required properties of photodetector?

- High quantum efficiency
- Low rise time or fast response
- Low dark current

52. Mention the important photodetector material. Why is it preferred?

InGaAsP. Since at long wavelengths, it has very low dark current, low risetime and high quantum efficiency.

53. What is the basic principle of photo diode?

When light is incident on the depletion region of the reverse-biased pn junction, the concentration of minority carriers increases. Therefore, reverse saturation current increases.

54. What is solar cell?

It is a p-n junction diode which converts solar energy (light energy) into electrical energy.

55. Mention any two merits and demerits of solar cell

Merits of Solar Cells:

- Renewable energy source
- Environmentally friendly

Demerits of Solar Cells:

- Intermittent energy production
- High initial cost

56. What is a photo detector?

It is a semiconductor device which is used to detect the presence of photons. This device is known as photo detector. It converts optical signals into electrical signals.

57. What are the types of photo detector?

There are three types of Photo-detectors:

(i) Photo emissive (ii) Photo conductive (iii) Photo voltaic

58. What is a Photo conductor?

The simplest solid – state photo detector is a piece of photo conducting semiconductor. It is also called a photo resistive device. It is based on the decrease in the resistance of certain semiconductors when they are exposed to light radiation (both infrared and visible). Such materials have a high dark resistance and low resistance on irradiation.

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- Varieties of LED's are available which emit light in different colors like red, green, yellow etc.
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- Used in various measuring devices such as range finders, **bar-code readers**.
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- Infrared and red laser diodes are common in **CD players**, **CD-ROM** and **DVD** technology. Violet lasers are used in **HE-DVD** and **Blue–ray** technology.
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- Up to **20% to 50%** cheaper than LCD processes.
- They hold the ability to handle streamlined video, which could revolutionize the display and cellular phone market.
- OLEDs are **paper-thin** and **consumes less power**.

66. What are drawbacks of OLED?

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- Color- The reliability of the OLED is still not up to the mark. After a month of use the screen becomes non-uniform.

67. What are the applications of OLED?

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- They can be used in television screens, computer displays, advertising information and indication.
- **OLED**s can also be used in light sources for general space illumination and large-area light-emitting elements.

68. Mention the condition to identify the band gap of a semiconducting material to be transparent to visible light?

For a semiconducting material to be transparent to visible light, its band gap should be larger than the energy of visible photons. Typically, a band gap of around **3 eV** or higher allows a material to be transparent to visible light.

69. Distinguish between fluorescence and phosphorescence

- Fluorescence involves short-lived emission, occurring almost immediately after absorption and stopping once the excitation source is removed.
- Phosphorescence, on the other hand, involves a delayed emission. The substance continues to emit light for a noticeable period even after the excitation source is removed. This delayed emission is often due to a longer-lived excited state or spin-forbidden transitions.

70. What is a photo-voltaic device?

Semiconductor junction photo diodes are called photo-voltaic devices.

71. What are types of photo-voltaic devices?

There are three Photo–voltaic devices:

- p-n Junction photo detector
- p-i-n photo diode
- Avalanche photo Diode (APD)

PART – B

1. Explain scattering of light in solids.
2. Describe absorption and emission of light in metal, insulator and semiconductor.
3. Explain carrier generation and recombination in semiconductor.
4. Describe excitons with example.
5. Describe the construction and working of photodiode.
6. Explain the construction and working of a solar cell.
7. Describe the construction and working of photo detector.
8. Explain the construction and working of a LED with energy band diagram. (May 2003)
9. Describe the construction and working of laser diodes. What are the advantages of these diodes?
10. What is OLED? Explain the basic concept of OLED, types, advantages, disadvantages and application.
11. Describe absorption and emission of light in metal, insulator and semiconductor.
12. Explain the construction and working of a solar cell.
13. Explain the construction, working, advantages and applications of LED
14. Describe the construction and working of laser diodes. What are the advantages of these diodes?
15. Explain the optical process in quantum wells
16. Explain in detail about excitonic state
17. What is optoelectronic devices? Explain light detectors in detail?
18. Explain organic semiconductors in optical process and devices
19. Explain in detail about optical absorption, loss and gain
20. Explain different types of modulators and switching devices

PART – A

1. What are metallic glasses?

Metallic glasses have the properties of metals and glasses such that they have ductility, malleability and brittleness. Ferromagnetic metallic glasses are in the form of ribbons and are used as light weight magnetic cores having no losses.

2. What are shape memory alloys?

Shape memory alloys or **SMART** materials or intelligent materials are the materials which respond with a change in shape on the application of mechanical stress along with the application of thermal or magnetic fields.

3. What are the applications of SMA's?

SMA's can act as actuators and sensors. Textile materials like SMA T-shirt can detect a variety of signals from the human body and weather conditions so as to allow from greater comfort. Fiber composite SMAs are used to produce twist on the helicopter blades. It is used in orthopaedic devices for pulling fractures together, artificial hearts and shrink-wrap.

4. 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.

5. What is meant by bottom-up approach in constructing nano materials?

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.

6. What is meant by top-down approach in constructing nano materials?

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.

7. What is quantum confinement?

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

8. 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.

9. 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.

10. 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

11. 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

12. 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.

13. 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.

14. What are non linear optical materials?

For very large intensities of light, as in lasers, it is observed that the refractive index of optical materials, frequency change with intensity and two photons interact with each other which make it possible to control light by using light. The superposition principle is not obeyed at such intensities. This behavior of light at large intensities is known as **non linear behavior** and the materials exhibiting this behavior are known as **non linear optical materials.**

15. What is self focusing in NLO materials?

The variation in intensity along the cross section of the beam causes the refractive index to vary along the cross section due to variation in the non linear effect. This causes the beam to focus without the use of lenses.

16. What are biomaterials?

Materials which are used as replacements for damaged human body parts like the hip joint, knee joint, teeth etc., are known as **biomaterials.**

17. Mention few biomaterials and their applications.

(i) **Stainless steels** (ASTMF-138 and ASTMF-139) have high tensile strength and high biocompatibility and are used as steel wires, plates and implant devices.

(ii) **Porous high density polyethylene** is used in dental and cortical implants.

(iii) **Ceramic implants** (SiO_2 and alkali metal oxide) are used to make femoral head.

18. 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 quantum 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 quantum wire.

19. What do you understand by quantum confinement? (May 2019)

It is process of reduction of the size of the solid such that the energy levels inside become discrete. It can be observed once the diameter of a material is of the same magnitude as the de Broglie wavelength of the electron wave function. When materials are this small their electronic and optical properties deviate substantially from those of bulk materials.

20. What are Nanodevices? (May 2018)

In the broadest sense, nanodevices are the critical enablers that will allow mankind to exploit the ultimate technological capabilities of electronic, magnetic, mechanical and biological systems.

21. 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.

22. 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.

23. 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.

24. 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.

25. What is quantum structure?

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

26. Define Zener-Bloch oscillation.

It denotes the oscillation of a particle (eg., an electron) confined in a periodic potential when a constant force is acting on it.

27. What is resonant tunneling?

The transmission probability of the double symmetric barrier is maximum and hence the tunneling current reaches peak value when energy of electron wave is equal to quantized energy state of the well. This phenomenon is known as resonance tunneling.

28. 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.

29. 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.

30. 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

$$W_C = \frac{e^2}{2C} >> k_B T$$

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.

31. 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.

32. What is a Single Electron Transistor?

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

33. 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.
- It is used for the fabrication of a homo-dye receiver operating at frequencies between **10** and **300 MHz**.

34. 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.

35. What is mesoscopic structure?

The structures which have a size between the macroscopic world and the microscopic or atomic are called mesoscopic structure.

36. What is conductance fluctuation?

Conductance (reciprocal of resistance) fluctuation in quantum physics is a phenomenon exhibited in electrical transport experiment in mesoscopic system.

37. 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.

38. What are the applications of quantum interference effect?

- Quantum interference effect is being applied in a variety of applications, such as Superconducting Quantum Interference Device (**SQUID**).
- Quantum cryptography
- Quantum computing and quantum interference transistor.

39. What are magnetic semiconductors?

The semiconducting materials which exhibit both ferromagnetism and useful semiconductor properties are known as magnetic semiconductors.

40. Give the examples for dilute magnetic semiconductor.

Oxide semiconductors:

- Zinc oxide
- Manganese-doped zinc oxide
- n-type cobalt-doped zinc oxide

Magnesium oxide:

- p-type transparent MgO films with cation vacancies

Titanium dioxide:

- Cobalt-doped titanium dioxide
- Iron-doped titanium dioxide
- Chromium-doped titanium dioxide
- Copper-doped titanium dioxide
- Nickel-doped titanium dioxide

41. 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.

PART- B

1. Give the concept, properties and applications of metallic glasses.
2. How are metallic glasses prepared? Explain how the melt spinner device can be used to produce metallic glasses (**MAY 2023**).
3. What is meant by SMA? Explain its working (**MAY 2022**).
4. Write short notes on (i) Metallic glasses (ii) SMA (iii) Nano materials
5. Explain quantum well, quantum wire and quantum dot.
6. Describe the carbon nano tubes with properties and applications.
7. Write short notes on Non Linear Optical (NLO) materials.
8. Explain the applications of Non Linear Optical (NLO) materials.
9. What are Biomaterials? Explain the different types of biomaterials.
10. Explain the electron density in bulk material and size dependence of Fermi energy.
11. Explain quantum confinement and quantum structures in Nano material.
12. Discuss density of states in quantum well, quantum wire and quantum dot structure.
13. Write note on Zener-Block oscillations resonant tunneling quantum interference effect.
14. Write note on mesoscopic structure, conductance fluctuations and coherent transport.
15. Explain coulomb blockade effect and single electron phenomena.
16. Describe construction and working of single electron transistor.
17. Write note on magnetic semiconductor.
18. Discuss on spintronics and also on spin based Field Effect Transistor.
19. Describe the carbon nano tubes with properties and applications.
20. Write a note on CNT (**AU May 2018**).
21. What are the key methods used in the preparation of metallic glasses, and how do they differ from conventional crystalline metal processing techniques?
22. Examine the electrical properties of metallic glasses, including their conductivity and resistivity. How do these properties make them suitable for specific electronic and electrical applications, and what are the limitations?
23. Explore the applications of metallic glasses across various industries, such as aerospace, automotive, electronics, and biomedical. What unique properties of metallic glasses make them advantageous for these applications, and what are some recent developments.
24. Investigate the challenges and limitations associated with the large-scale production and commercialization of metallic glasses. What technological advancements are needed to overcome these challenges and expand the market for metallic glasses?
25. What are the fundamental characteristics of shape memory alloys (SMAs), and how do they differ from conventional metals in terms of their ability to exhibit shape memory effect and super elasticity?

26. Discuss the crystal structure and phase transformation behavior of Ni-Ti (nickel-titanium) alloy, the most widely studied and utilized shape memory alloy. How do these structural features contribute to its unique properties?

27. How can nanomaterials revolutionize the efficiency and performance of electronic devices?

28. How could nanomaterials enable the development of smaller, more powerful mobile electronic devices?

29. How can nanomaterials be engineered to enhance the durability and reliability of electronic components?

30. What challenges need to be addressed to ensure the safe production and disposal of nanomaterials used in electronics?

31. What ethical considerations should be taken into account regarding the use of nanomaterials in electronic devices and robotics?

32. How do quantum size effects manifest in nanomaterials, particularly in quantum dots, wires, and wells?

33. What are the unique properties and potential applications of quantum dots in various fields such as optoelectronics and biomedical imaging?

34. How do different types of carbon nanotubes vary in structure, properties, and potential applications?

35. What are the challenges and opportunities in the large-scale synthesis and manufacturing of carbon nanotubes for industrial applications?

36. How can quantum wires be engineered to manipulate electron transport and conductivity in nanoelectronics devices?

37. What are the recent advancements in the fabrication and characterization of quantum wells and their implications for photonics and semiconductor technology?

38. How can the controlled growth and assembly of nanomaterials, such as quantum dots and carbon nanotubes, be achieved for tailored applications?

39. Explore the classification of biomaterials according to their intended function, such as structural, functional, and bioactive biomaterials. Explain how each category serves specific purposes and provide examples of biomaterials within each classification along with their applications.

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