2. *Mention any two active and passive dielectrics with their applications (or) Compare active and passive dielectrics.* **(April 2003, June 2009)**

S.No.	Active dielectrics	Passive dielectrics
1.	Dielectrics which can easily adapt itself to store the electrical energy in it is called active dielectrics.	Dielectrics which restricts the flow of electrical energy in it are called passive dielectrics
2.	**Examples:** Piezo electrics Ferro electrics, Pyro electrics	**Examples:** glass, mica, plastic
3.	It is used in the production of ultrasonics.	It is used in production of sheets, pipes etc.,

3. *Define electronic polarisation.* **(April 2003, May 2011)**

When a dielectric material is kept in external field (E), the positive and negative charges in the dielectrics moves in opposite direction, thereby creating a dipole moment. This process is known as electronic polarisation.

The induced dipole moment $\mu = \alpha_e E$

where $\alpha_e \rightarrow$ electronic polarisation.

4. *Define local (or) internal field in dielectrics.* **(Nov. 2003, Dec 2003)**

When a dielectric is kept in an external electric field (E), two fields are exerted due to (i) external field and (ii) dipole moment created. These long range of coulomb forces which are created due to the dipoles are called internal field (or) local field in dielectric.

It is given by $E_{int} = E + \frac{P}{3\varepsilon_o}$

where $P \rightarrow$ Polarisation

$\varepsilon_o \rightarrow$ Permitivity in free space

5. *What is meant by dielectric loss and loss tangent? Why it occurs?* **(Nov 2002, June 2005, June 2009, June 2010, May 2011)**

When a dielectric material is subjected to electric field, the electrical energy is absorbed by the dielectric and certain amount of electrical energy is dissipated in the form of heat energy. This loss in energy in the form of heat is called dielectric loss.

The power loss $P_L \propto \tan\delta$, where $\tan\delta$ is called loss tangent and δ is called loss angle.

This dielectric loss mainly occurs due to the imaginary part of complex dielectric constant.

What is meant by dielectric breakdown and dielectric strength.

(April 2002, May 2009, June 2010, May 2011, June 2012)

Dielectric Breakdown: When external field applied to a dielectric material is greater than the critical field, the dielectric losses its insulating property and becomes conducting. Therefore a large current flows through the material. This phenomenon is called dielectric break down.

Dielectric strength: It is the minimum strength (voltage) required per unit thickness of the dielectric material to produce dielectric breakdown.

7. *Explain electrochemical breakdown in dielectric.* **(May 2003)**

This type of breakdown occurs due to the presence of coirs and their mobility. These impurities causes leakage current and energy loss in the materials. Thus, when the temperature of the dielectric material is increased, due to the presence of coirs the chemical reaction is accelerated and hence the material becomes conducting, causing electrochemical breakdown.

8. *Mention the various dielectric breakdown mechanisms.* **(Dec 2005)**

(a) Intrinsic break down (b) Thermal break down

(c) Discharge break down (d) Electrochemical break down

(e) Defect break down

9. *The dielectric constant of water is 80. Is water a good dielectric? Is it useful for energy storage in capacitors? Justify your answer.* **(May 2011)**

Though the dielectric constant of water is 80 at 20°C (or) 293 K, it is not a good dielectric material, because of the following reasons, viz,

1. At normal temperature the electrical conductivity of water is very high.
2. At normal temperature current lead the voltage by a very less angle i.e., $\cos\theta$ is very less, which leads to very high loss angle (δ) and hence $\tan\delta$ is very high.
3. The dissipation factor and hence the power loss is very high.

Thus, water cannot be used as dielectric for energy storage in capacitors.

10. *What are the requirements of good insulating materials?* **(June 2010, May 2011)**

1. It should have low dielectric constant.
2. It should possess low dielectric loss.
3. It must have high resistance.
4. It must possess high dielectric strength.
5. It should have adequate chemical stability.
6. It must have high moisture resistance.

11. *What are dielectric materials? Give its properties.* **(June 2009, May 2011)**

Dielectrics are non-metallic materials which have permanent electric dipoles (or) has an ability to produce enormous induced dipoles in the presence of external electric field.

Properties

(i) It has high specific resistance.

(ii) It has negative temperature coefficient of resistance.

(iii) large insulation resistance.

12. *Define dielectric constant.* **(June 2010, May 2011)**

Dielectric constant (ε_r) is the measure of the polarisation produced in the material. It is the ratio between the absolute permittivity (ε) and the permittivity of free space (ε_o).

$$\text{(i.e.,)}\ \varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$$

13. *What are the microscopic polarisation mechanism involved in dielectric polarisation?* **(June 2009)**

There are four mechanisms involved in electric polarisation.

(i) Electric polarisation

(ii) Ionic polarisation

(iii) Orientation polarisation

(iv) Space-charge polarisation

14. *Define ionic polarisation.* **(Dec. 2009, June 2010)**

The process of displacement of cations and anions in the opposite directions, of a dielectric material kept in external electric field (E) is called ionic polarisation.

Induced dipole moment $\mu = \alpha_i E$

where α_i ionic polarisability.

15. *Define orientation polarisation.* **(Dec. 2009)**

The orientation of polar molecules with respect to the field direction is called orientation polarisation (P_o)

$$\text{i.e., } P_o = N \alpha_o E$$

where $N \rightarrow$ Number of atms

$\alpha_o \rightarrow$ Orientation Polarisability

16. *What are the different break down mechanisms that occur in a dielectric material?* **(June 2009, May 2011)**

The following are the break down mechanisms that occur in dielectrics.

(i) Intrinsic (or) Avalanche breakdown

(ii) Thermal breakdown

(iii) Chemical and electrochemical breakdown

(iv) Discharge breakdown

(v) Defect breakdown

17. *Discuss the discharge and defect breakdown in dielectrics.* **(Dec. 2009)**

Discharge breakdown: when a dielectric is placed in an external electric field, the occluded gas bubbles present in the materials will easily ionise and produces large ionization current. This phenomenon is known as discharge break down.

Defect breakdown: These breakdown occurs due to the defects such as pores, cracks, etc in the dielectrics. These vacant positions which consists of impurities produces breakdown and hence called defect breakdown.

ADDITIONAL PART A QUESTIONS & ANSWERS

1. *Define polarisation vector and electric displacement vector.*

Polarisation vector ($\vec{P}$): It is defined as the dipole moment per unit volume.

$$\text{(i.e.,)} \quad \vec{P} = \frac{\mu}{V}$$

Electric displacement Vector ($\vec{D}$): It is the amount of electric flux/energy per unit area

$$\text{(i.e.,)} \quad \vec{D} = \frac{Q}{A}$$

2. *Prove $\chi_e = \varepsilon_r - 1$*

We know polarisation $\vec{P} = \varepsilon_o \chi_e \vec{E}$ ... 1

$$\text{(or)} \quad \chi_e = \frac{\vec{P}}{\varepsilon_o \vec{E}} \quad \text{...(1)}$$

$$\text{Since} \quad \frac{\vec{P}}{\vec{E}} = \varepsilon_o (\varepsilon_r - 1)$$

$$\text{(or)} \quad \frac{\vec{P}}{\varepsilon_o E} = \varepsilon_r - 1 \quad \text{...(2)}$$

Comparing equation (1) and (2) we get

$$\boxed{\chi_e = \varepsilon_r - 1}$$ Thus proved.

3. *Distinguish Lorentz force and Coulomb force in dielectrics.*

Lorentz force: It is the repulsive force between the nucleus and the electron cloud of a dielectric material when kept in external electric field.

Coulomb force: It is the attractive force between the nucleus and the electron cloud, which try to maintain the equilibrium position of the dielectric material kept in an external electric field.

4. *Define space charge polarisation.*

When a dielectric is placed in an electric field the diffusion of ions take place along the field direction, giving rise to redistribution of charges in the dielectrics and this phenomenon is known as space charge polarisation.

5. Compare the electronic and orientation polarisation.

S.No	Factor	Electronic polarization	Orientation polarization
1.	Definition	Electron clouds are shifted with respect to nucleus	Alignment of random molecules takes place
2.	Examples	Inert gases	Alcohol, methane, CH_3Cl
3.	Temperature dependent	Independent of temperature	Dependent of temperature
4.	Relaxation time	very fast	slower
5.	Power loss	low	higher
6.	Frequency range	Frequencies upto 10^{15} Hz and above.	Frequencies about 10^{12} Hz

6. What are the ways in which the dielectric breakdown can be minimised.

The electric breakdown can be minimised by choosing the material with the following properties.

(i) It should possess high dielectric strength and low dielectric loss.

(ii) It should have less density and thermal expansion.

(iii) It should have high resistivity and sufficient mechanical strength.

(iv) It should be pure.

(v) It should not possess any defects.

7. Define Gauss law and write the equation for the total flux, when the charge is placed inside the surface and outside the surface.

The total Electric flux (φ) or the Total Normal Electric Induction (T.N.E.I) of the electric field $\vec{E}$ *over any closed surface is equal to* $\frac{1}{\varepsilon_0}$ *times the total charge enclosed by the surface.*

$$\therefore \phi = \oint_S \vec{E} \cdot d\vec{S} = \frac{\Sigma q}{\varepsilon_0}$$

Case (i) When the electric charge is situated inside the closed surface

The total flux through the entire closed surface is given by

$$\therefore \phi = \frac{q}{\varepsilon_0}$$

Case (ii) For a charge outside the sphere

$$\text{The Total flux} = -\frac{q}{4\pi\varepsilon_0}\,d\omega + \frac{q}{4\pi\varepsilon_0}\,d\omega = 0$$

8. *What are the uses of Gauss law?*

1. It is used to find the electricfield. If, the charge distribution is so symmetric, by constructing a closed surface (Gaussian surface), the electric field can be find out.

2. Gauss's law is one of the fundamental equation of electromagnetic theory. i.e., it is one of the Maxwell's equations.

3. One can derive coulomb's law from Gauss's law. So, Gauss's law is more fundamental than coulomb's law.

9. *Mention some of the solid insulating materials and its uses.*

(a) Mica

It is made of silicate aluminium with silicates of soda potash and magnesia.

Uses

1. It is used as insulator in commutator segment.
2. It is used in the form of tapes in high voltage alternators.

(b) Asbestos

It is a naturally occuring mineral material of fibrous structure made of magnesium silicate.

Uses

1. It is used in electrical machines to withstand high temperature.
2. It is used in the form of paper, tape, cloth and board, for insulation.

(c) PVC (Poly Vinyl Chloride)

It is produced by treating acetylene and hydrogen chloride in the presence of a catalyst at a temperature of about 50°C.

Uses

1. It is used in the manufacturing of PVC films, tapes and pipes.
2. It is used as insulation for batteries, conductors and cables.

10. Give some of the liquid insulating materials and its uses.

(i) Synthetic Insulating Oils

When we compare this with mineral insulating oil, the properties are degraded. Askarels have thermal stability upto 110°C and are manufactured from chlorinated hydro-carbons.

Uses

They are used as coolant and insulant in high voltage transformers.

(ii) Miscellaneous Insulating Oils

Silicon liquids are costly and they have stability upto 200° C. Vaseline has high viscosity and high dielectric constant. It is used for impregnation of papers used in capacitors.

Uses

1. They are used in High Voltage (H.V) transformers.
2. They are used to increase the surface resistivity of ceramic insulators.

11. List some of the gas insulating materials and its uses.

(i) Vacuum

Vacuum means free space without air. So creating a vacuum place is a type of insulation.

Uses

It is used in (i) X-ray tubes (ii) Electronic valves (iii) Particle accelerators (iv) Microwave tubes (v) Low-loss capacitors, etc.

(ii) Air

Air is a naturally occuring dielectric. The atmospheric gas consists of a number of gases say N_2, O_2, He, CO_2, Ne etc.

Uses

(i) They act as insulators in switches, plugs and various electrical machines.

(ii) They are used in low voltage applications.

12. Define capacitor and mention its unit.

A capacitor or a condenser is a device which essentially consists of two conducting surfaces separated by an insulating material, (called dielectric) say oil (or) mica. The capacitance of a capacitor increases with the presence of a dielectric.

$$C = \frac{q}{V} \text{ coulomb/volt}$$

13. Mention some of the types of capacitors. Give examples.

Capacitors can be classified into three categories

(a) Capacitors with solid dielectric

(b) Capacitors with air as the dielectric

(c) Electrolytic capacitors

Examples for capacitors with solid dielectric

The Leyden Jar, Mica capacitor, Paper capacitor.

Example for capacitors with air dielectric

Variable air capacitor.

14. Give any four applications of dielectrics in transformer.

(i) Synthetic oils are used as coolant and in high voltage transformers.

(ii) Mineral oils are used as transformer oils.

(iii) Petroleum oils are used in transformers and circuit breakers.

(iv) Miscellaneous oils such as vegetable oils, vaseline etc are used in High Voltage transformers.

15. Write any four applications of dielectrics in capacitors.

(i) Ceramic materials are used in high frequency capacitors and disc capacitors.

(ii) Electrolytic solution of sodium phosphate and ammonium tetraborate are used as wet type and dry type electrolytic capacitors respectively.

(iii) Mica is used in discrete capacitors.

(iv) Papers filled with synthetic oils are used in power capacitors.

16. Define piezoelectricity and list some of the piezo electric crystals.

When mechanical stress is applied on dipolar crystals, electricity is produced due to the displacements of dipoles. This phenomenon is called piezoelectricity and those crystals that exhibit this property are termed as piezoelectric crystals.

Examples

Quartz, Topaz, Tourmaline Barium titanate, Rochelle salts, Lead titanate, etc. are some of the examples for piezoelectric crystals.

17. Give any two properties and applications of a piezoelectric crystals.

Properties

(i) Piezoelectricity phenomenon exists due to crystal anisotrophy (amorphous materials are not piezoelectric)

(ii) Piezoelectricity and pyroelectricity have linear effect.

Applications

(i) Piezoelectric crystals are used in microphones, ultrasonic devices, sonar detector etc.

(ii) Piezoelectric crystals acts as a transducer and is used to generate ultrasonic waves.

18. Define pyro electricity and list some pyzo electric crystal.

Pyro means heat, some piezoelectric crystals when heated, then it produces electricity to a small extent and this phenomenon is called pyroelectricity. The crystals that exhibit this phenomenon are called pyroelectric crystals.

Examples

Tourmaline, Gallium nitride, Cesium nitrate ($CsNo_3$) Lithium tantalite ($LiTaO_3$) are some of the examples of pyroelectric crystals.

19. List any two properties and applications of pyroelectric crystals.

Properties

(i) Pyro electric crystals will have unidirectional polarization

(ii) These crystals are Non-centro symmetric in nature.

Applications

(i) The pyroelectric crystals are used in IR detectors, elements.

(ii) These are also used in temperature sensors.

20. What is meant by ferroelectricity? Mention some of the ferroelectric materials?

*When a dielectric material exhibits electric polarisation even in the absence of external field, it is known as **ferro-electricity** and these materials are termed as **ferro-electrics**.*

Examples

(i) Rochelle salt, (ii) Barium titanate,
(iii) Potassium niobate, (iv) Lithium niobate,
(v) Lithium tantalate, (vi) Lead-zirconate

21. *Mention some of the properties ferroelectric materials.*

Properties

(i) The dielectric constant of these ferro-electric material is above 2000 and it will not vary with respect to temperature.

(ii) The dielectric constant (ε_r) reaches maximum value only at a particular temperature called ***curie temperature***.

(iii) The polarization does not varies linearly with respect to electric field and hence these materials are also called as ***non-linear dielectrics***.

(iv) Ferro-electrics exhibits electric polarisation very easily. even in the absence of external electric field.

22. *List out some of the applications of ferroelectric materials.*

Applications

(i) Ferro-electric materials are used to produce ultrasonics.

(ii) They are used in the production of piezo-electric materials and in turn to make microphones.

(iii) Ferro-electrics are also used in SONAR, strain gauges, etc.

(iv) Ferro-electric semiconductors are used to make positors, which is turn are used to measure and control the temperature.

(v) They are also used as frequency stabilizers and crystal controlled oscillators.

23. *What is meant by an oscillator? Give its types.*

Oscillators

Oscillators are defined as the circuit which converts D.C. energy to A.C. energy at a very high frequency.

Types

Electronic oscillators may be broadly divided into the following types *viz.*,

(i) Sinusoidal (Harmonic) oscillators – which produces an output in the form of sine waveform.

(ii) Non-sinusoidal (relaxation) oscillators – which produces an output in the form of square, rectangular, saw-tooth (or) pulse shape (other than sine wave form).

UNIT 1

24. Give some of the applications of Quartz oscillator.

Applications

1. Due to the extreme stability of crystal these oscillators are used in communication transmitters and receivers.
2. Crystal oscillators are compact in size and low cost therefore it may be used in electronic guidance systems, such as microprocessors, microcontrollers, etc.,
3. It is also used in Space tracking system, modems, sensors, Global positioning systems (GPS).
4. These crystal oscillators plays a vital role in cable television system, video cameras, cellular phones, etc.

25. What are the advantages and disadvantages of Quartz oscillator.

Advantages

1. They have high order of frequency stability.
2. The quality factor of the crystal is very high.

Disadvantages

1. They are easily broken and can be used in low power circuits.
2. The frequency of oscillations cannot be changed appreciably.

26. What is meant by a filter? List out its applications.

A filter circuit passes one band of frequency and rejects another band of frequency (without any attenuation).

Applications

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27. *What do you understand by the term pass band, stop band and bandwidth?*

(i) Pass band

The band of frequencies of the input signal that pass through the filter without any attenuation is called ***pass band*** as shown in ***Fig. 1A***

(ii) Stop band

The band frequencies of the input signal that are blocked (or) attenuated in filters are called ***stop band*** as shown in ***Fig. 1A.***

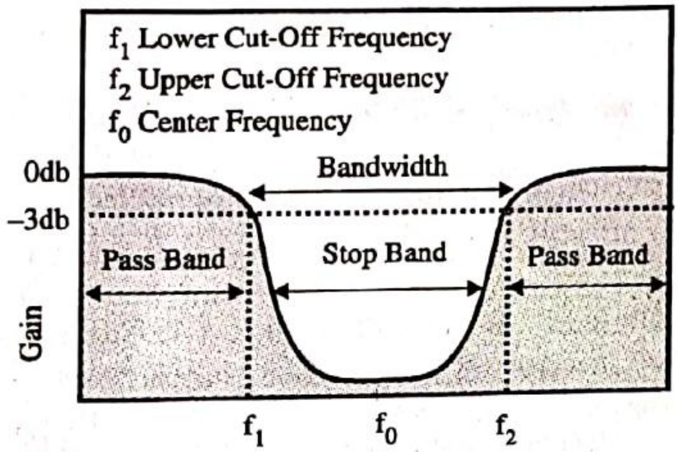


Fig. 1A

(iii) Bandwidth

The range of frequencies that are passed (band pass filter) without any attenuation (or) the frequencies that are attenuated (band reject filter) is called ***bandwidth*** **(β)** ***of the filter*** as shown in ***Fig. 1A.***

It is the difference between the cut-off frequency f_2 and f_1 of the band pass (or) band reject filter.

i.e., $$\beta = f_2 - f_1$$

28. *What is meant by Active filter and passive filter?*

(i) Active filters

Active filters are made up of resistors, capacitors along with operational amplifier (or) transistors and other active components.

(ii) Passive filters

Passive filters are made up of passive components, such as resistors, capacitors and inductors.

29. *Classify the types of filter based on their frequency response.*

Based on the frequency response, the filters are further classified into five categories, *viz.*,

(i) Low pass filter

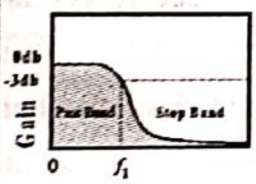
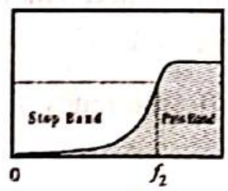
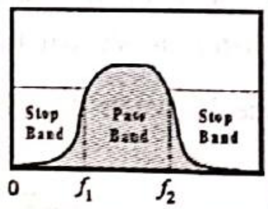
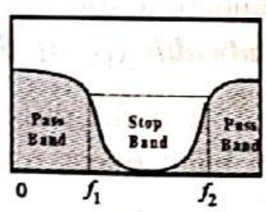
(ii) High pass filter

(iii) Band pass filter

(iv) Band reject filter

(v) All pass filter

30. *Compare the various types of filters.*

Sl.No.	Low pass filter	High pass filter	Band pass filter	Band reject filter
1.	Passes all frequencies from zero to cut-off frequency (f_1) and blocks the remaining frequencies.	Blocks all frequencies from zero to cut-off frequency (f_2) and allows the remaining frequencies.	Passes the frequencies from lower cut-off region (f_1) to higher cut-off region and blocks the (f_2) remaining frequencies.	Blocks the frequencies from lower cut-off region (f_1) to higher cut-off region (f_2) and passes the remaining frequencies.
2.	It has one vertical transition.	It has one vertical transition.	It has two vertical transitions.	It has two vertical transitions.
3.	It has zero attenuation in pass band and infinite attenuation in stop band.	It has zero attenuation in pass band and infinite attenuation in stop band.	It has zero attenuation in pass band and infinite attenuation in stop band.	It has zero attenuation at all frequencies.
4.				

1. *Define electrical conductivity.* **(April 2002)**

The electrical conductivity is defined as the quantity of electricity flowing per unit area per unit time maintained at unit potential gradient.

Unit: $\Omega^{-1} M^{-1}$

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

where $n \rightarrow$ Number of free electrons per unit volume

$e \rightarrow$ charge of an electron

$\tau \rightarrow$ Relaxation time

$m \rightarrow$ mass of an electron

2. *Define Mobility of Electrons.* **(April 2003, June 2009)**

When electric field (E) is applied to metals, the electrons moves in the direction opposite to the field direction with the velocity 'v', then mobility of an electron is defined as the velocity acquired by the electron per unit electric field (E).

$$\text{(i.e.)} \ \mu = \frac{v}{E}$$

3. *Give the postulates of free electron theory.* **(June 2009, May 2011)**

(i) The free electrons in the metal moves freely, similar to the gas molecules moving in a vessel and it obeys the classical kinetic theory of gases.

(ii) These free electrons moves in a constant potential field due to ions fixed in the lattice.

(iii) When field is applied the free electron moves in the direction opposite to that of the field direction.

(iv) Due to field applied, they acquire a velocity called drift velocity and the electron velocities in the metal obeys the Maxwell-Boltzmann statistics.

4. *Define Drift velocity and give its formula.* **(June 2010, June 2011)**

Drift velocity is defined as the average velocity acquired by the free electron in a particular direction, due to the application of electric field and is denoted by the letter v_d

Formula: $v_d = \frac{e \tau_c E}{m}$

where $e \rightarrow$ charge of the electron

$\tau_c \rightarrow$ mean collision time

$E \rightarrow$ field applied

$m \rightarrow$ mass of the electron

5. *Distinguish between relaxation time and collision time.* **(June 2009)**

S.No.	Relaxation Time (τ)	Collision time (τ_c)
1.	It is the time taken by the free electron to reach its equilibrium position from its disturbed position, due to the field applied.	It is the average time taken by a free electron between two successive collision.
2.	$\tau = 10^{-14}$ seconds (Approx)	$\tau_c = \lambda / \overline{c}$ where $\lambda \rightarrow$ mean free path $\overline{c} \rightarrow$ Root mean square velocity

6. *Define mean free path.* **(June 2009, June 2012)**

The average distance travelled between two successive collisions is called mean free path. It is denoted by the letter 'λ'.

Mean free path $\lambda = \overline{c}\, \tau_c$

where $\overline{c} \rightarrow$ Root mean square velocity of the electron

$\tau_c \rightarrow$ Collision time

UNIT 2

7. Mention any two important features of quantum free electron theory of metals. (April 2003)

(i) It shows that the energy levels of an electron are discrete

(ii) The Maximum energy level upto which the electrons can be filled is denoted by Fermi energy level.

8. Get the microscopic form of Ohm's law and state whether it is true for all temperatures? (June 2009)

According to classical free electron theory current density

$$J = \sigma E$$

where $\sigma \rightarrow$ electrical conductivity

since conductivity $(\sigma) = \frac{1}{\text{Resistivity } (\rho)}$, we can write

$$E = J\rho$$

For a conductor of length 'l' and area of cross section 'A'

Resistance $= \frac{\rho l}{A}$

$\therefore$ Voltage $V = I \frac{\rho l}{A}$

(or) $V = IR$

$\therefore$ Microscopically we can write $V = IR$ as $E = J\rho$

Since the resistivity varies with respect to the temperature, the microscopic form of Ohm's law is not true for all the temperatures.

9. What are the source of resistance in metals? (Nov. 2003)

The resistance in metals is due to

(i) Impurities present in the metals

(ii) Temperature of the metal

(iii) Number of free electrons

10. Define Wiedemann-Franz law. Give the value of Lorentz number and state whether it holds good for all metals and at all temperatures? (June 2007, June 2009, Dec. 2009, June 2010, May 2011)

Wiedemann-Franz law is defined as, "the ratio between the thermal conductivity (K) and the electrical conductivity (σ) of a metal is directly proportional to the absolute temperature (T) of the metal".

11. What are the drawbacks of classical free electron theory

(June 2005, June 2007, June 2009, June 2010, May 2011)

(i) It is a macroscopic theory

(ii) Classical theory states that all free electrons will absorb energy, but quantum theory states that only few electrons will absorb energy.

(iii) This theory cannot explain the Compton, photo-electric effect, paramagnetism, ferromagnetism, etc.

(iv) The theoretical and experimental values of specific heat and electronic specific heat is not matched.

(v) By classical theory $\frac{K}{\sigma T}$ = constant for all temperatures, but by Quantum theory $\frac{K}{\sigma T} \neq$ constant for all temperatures.

(vi) The Lorentz number by classical theory does not have good agreement with the experimental value and is rectified by quantum theory.

12. Define Fermi energy level and Fermi energy with its importance.

(Nov. 2002, Nov 2005, June 2007, June 2009, June 2010, May 2011, June 2012)

Fermi energy level: It is the highest reference energy level of a particle at absolute zero. It is the state at which the probability of electron occupation is 50% at any temperature.

Importance: It is the reference energy level which separates the filled energy levels and vacant energy levels.

Fermienergy **(E_F):** It is the maximum energy of the quantum state corresponding to Fermi energy level at absolute zero. It is also the energy of thestate at which the probability of electron occupation is 50% at any temperature.

Importance: Fermi energy determines the energy of the particle at any temperature.

13. Write the Fermi-dirac distribution function and give its importance.

(April 2003, Nov. 2003, Dec. 2003, June 2010, May 2011)

Fermi function F(E): Fermi-dirac distribution function represents the probability of an electron occupying a given energy level. It is given by

$$F(E) = \frac{1}{1 + e^{(E - E_F)/K_B T}}$$

where $K_B \rightarrow$ Boltzmann constant

$T \rightarrow$ Absolute Temperature

U N I T 2

UNIT 2

Importance: It gives the probability of filling the electron within the Fermi energy level.

For example if $F(E) = 0.7$ means, there is 70% chance for filling an electron within the Fermi energy level.

14. *Draw the Fermi distribution curve at OK and at any temperature TK. (or) How does the Fermi function varies with temperature?*
(Nov. 2003, June 2009, Dec. 2009, June 2010, May 2011)

The Fermi function varies with respect to the temperature as shown in ***Fig. 1(a)*** Here at 0 K all the energy states below E_{F_0} are filled and all those above it are empty. Now when the temperature is increased, the electron takes an energy K_BT and hence the Fermi function falls to zero.

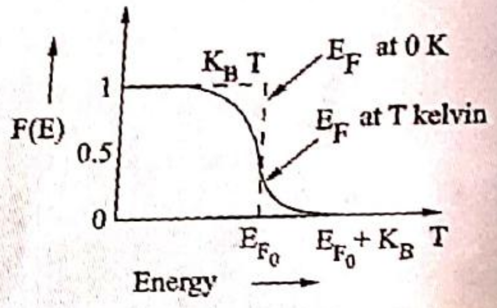


Fig. 1(a)

15. *What is meant by Fermi energy of a metal?* **(April 2002, Nov. 2002)**

Fermi energy is the energy of the quantum state corresponding to the Fermi energy level at absolute zero.

It is the maximum energy that an electron in a metal can possess at absolute zero.

16. *Define density of states and given an example and state its importance.* **(Dec. 2003)**

Define density of states and sketch the same for a metal. **(May 2008, June 2010, May 2011)**

Definition: Density of states $Z(E)dE$ is defined as the number of available energy states per unit volume in an energy interval dE.

Example

We can say the density of states of a cubical metal piece ([***Fig. 1(b)***] as

$$Z(E)\,dE = \frac{\text{Number of available energy states between } E \text{ and } E + dE \text{ in a cubical metal piece}}{\text{Volume of that cubical metal piece}}$$

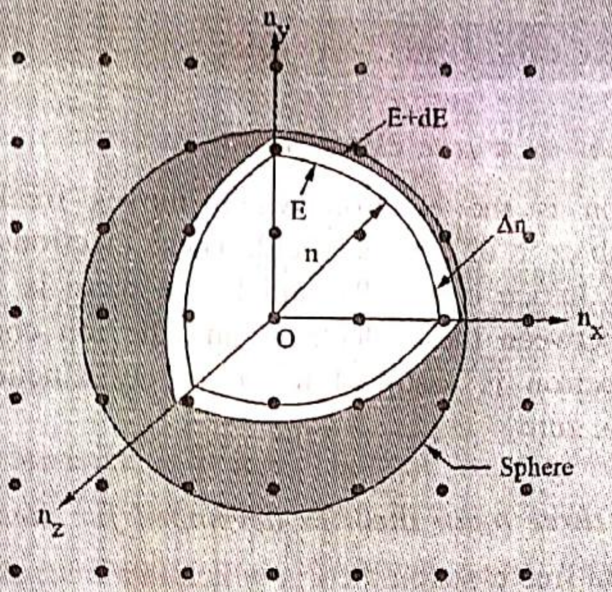


Fig. 1(b)

Importance: It is used to calculate the number of charge carriers per unit volume of any solid.

17. Write a note on effective mass of an electron moving in a periodic potential. ***(Nov. 2003)***

Definition:

Effective mass of an electron is the mass of the electron when it is accelerated in a periodic potential and is denoted by m^*

Explanation:

We know mass of an electron is constant, but it is found to vary, when it is accelerated in a periodic potential and this varying mass is called as effective mass, given by

$$m^* = \frac{\hbar^2}{d^2E/dk^2}$$

The effective mass depends on the value of $\frac{d^2E}{dk^2}$ (ie)

(i) If $\frac{d^2E}{dk^2}$ is positive; m^* is also positive

(ii) If $\frac{d^2E}{dk^2}$ is negative; m^* is negative

(iii) If $\frac{d^2E}{dk^2}$ is zero; m^* becomes infinite.

Mostly $m^* = m$ for metals and $m^* \neq m$ for semiconductors and insulators.

ADDITIONAL PART-A QUESTIONS & ANSWERS

1. *What is meant by a free electron?*

Free electron is the electron which moves freely (or) randomly in all directions in the absence of external field. These electrons collides with each other and also with the lattice elastically and hence there is no loss in energy. Also, since the forces between these electrons and the ion core is neglected, the total energy of the electron is assumed to be purely kinetic energy and hence the potential energy is zero.

2. *List out the three main theories developed for metals.*

(i) Classical free electron theory, which is a macroscopic theory and it obeys classical laws.

(ii) Quantum free electron theory, which is a microscopic theory and it obeys quantum laws.

(iii) Zone theory (or) band theory is also a microscopic theory which is based on the energy bands of solids.

3. *What are the differences between Drift velocity and thermal velocity of an electron.*

S.No.	Drift velocity	Thermal velocity
1.	Drift velocity is the average velocity acquired by the free electron, in the presence of electric field.	Thermal velocity is the velocity of an electron without any external field.
2.	The electrons moving with drift velocity moves in the direction opposite to that of the field direction	The direction of the electrons moving with thermal velocity is random
3.	The velocity is very less, say in the order of 0.5 m/s	The velocity is very high, say in the order of 10^5 m/s

4. Distinguish between electrical conductivity and thermal conductivity.

S.No.	Electrical Conductivity	Thermal Conductivity
1.	The Co-efficient of electrical conductivity is defined as the quantity of ***electricity flowing*** per unit area per unit time maintained at unit potential gradient.	The Co-efficient of Thermal conductivity is defined as the quantity of ***heat conducted*** per unit area per unit time maintained at unit temperature gradient.
2.	Electrical conductivity is purely due to number of free electrons.	Thermal conductivity is due to both free electrons and phonons.
3.	Conduction of electricity takes place from higher potential end to the lower potential end.	Conduction of heat takes place from hot end to cold end.
4.	**Unit:** $ohm^{-1} m^{-1}$	**Unit:** $Wm^{-1} K^{-1}$

5. *What are the similarities between electrical and thermal conductivity of metals?*

1. The electrical and thermal conductivity decreases with the increase in temperature and impurities.
2. The electrical and thermal conductivity is very high at low temperature.
3. For non-metals, the electrical and thermal conductivity is very less.

6. *What are the success of classical free electron theory.*

(i) It verifies Ohms law.

(ii) It explains the electrical and thermal conductivity of metals.

(iii) It is used to derive Wiedemann - Franz law.

(iv) The optical properties of metals can be explained using this theory.

7. *Discuss the variation of resistivity of a conductor with respect to temperatures.*

The variation of resistivity with respect to temperature can be explained as follows.

(i) The resistivity of a conductor remains almost constant at lower temperatures. ($\rho = \text{constant}$)

(ii) The resistivity is proportional to T^5 i.e., $\rho \propto T^5$ from low temperature to the Debye temperature.

(iii) The resistivity is directly proportional to T i.e., $\rho \propto T$, above Debye Temperature.

8. What is meant by degenerate and non-degenerate states.

(i) Degeneracy: *It is seen from equation (28) and equation (29), for several combination of quantum numbers we have same energy eigen value but different eigen functions. Such states and energy levels are called **Degenerate State.***

The three combination of quantum numbers (112), (121) and (211), which gives same eigen value but different eigen functions are called **3 fold degenerate state.**

(ii) Non-Degeneracy: *For various combinations of quantum number if we have same energy eigen value and same (one) eigen function then such states and energy levels are called **Non-Degenerate State.***

Example

For $n_x = 2$ $n_y = 2$ $n_z = 2$ we have $E_{222} = \frac{12\, h^2}{8ma^2}$ and

$$\psi_{222} = \sqrt{\frac{8}{a^3}}\sin\frac{2\pi x}{a}\sin\frac{2\pi y}{a}\sin\frac{2\pi z}{a}$$

9. What are the differences between quantum theory and zone theory?

S.No.	Quantum theory	Zone theory
1.	Here the electron is assumed to move in a region of constant potential.	In zone theory the electron is assumed to move in a region of periodic potential
2.	According to this theory the mass of the electron remains constant, when it moves through constant potential	Accordingly to zone theory the mass of the electron varies when it moves through periodic potential and is called effective mass of an electron.
3.	If fails to explain why some solids behaves as conductors, some behave as insulators and semi conductors.	It explains the behaviour of solids as conductors, semiconductors and insulators

10. Define zero probability, unit probability and fractional probability.

Zero probability: It is the state which remains always empty and the electrons cannot be filled in it, i.e., $F(E) = 0$

Unit probability: It is the state which is always filled with the electrons, i.e., $F(E) = 1$

Fractional probability: It is the state which may be filled (or) empty (or) partially filled by electrons (or) it is the state which is filled by the electrons for some time and then will become empty, i.e., $F(E)$ will be a fraction like 0.5, 0.6 etc.

11. What is meant by tunnelling effect?

In quantum mechanics a particle having lesser energy (E) than the barrier potential (V) can easily cross over the potential barrier having a finite width 'l' even without climbing over the barrier by tunnelling through the barrier. This process is called Tunnelling.

12. Mention any four occurrences of tunnelling effect.

1. The tunnelling effect is observed in Josephson junction, in which electron pairs in the super conductors tunnel through the barrier layer, giving rise to Josephson current.
2. This effect is also observed in the case of emission of alpha particles by radioactive nuclei.
   Here, though the 'α' particle has very less kinetic energy they are able to escape from the nucleus whose potential wall is around 25 MeV high.
3. Tunnelling also occurs in certain semiconductor diodes called tunnel diodes.
4. Electron tunnels through insulating layer and act as a switch by tunnelling effect.

13. What do you understand by Fermi-dirac statistics and define fermions.

In the case of Fermi-dirac statistics the following points are considered.

(i) The particles (electrons) are indistinguishable.

(ii) The electrons which obey the Fermi-dirac statistics are called as ***fermions.***

(iii) Each energy state can have only one particle with one spin.

(iv) The number of energy states should be greater than (or) equal to number of particles, for example to fill say 9 particles, atleast 9 states should be available.

(v) There is no restriction in choosing the particle, (i.e) we can choose any particle to fill in any state.

(vi) The total energy of the system = Sum of all the energies of the particles.

UNIT 2

14. *Define scattering power of the potential barrier.*

Scattering power of a potential barrier is defined as the strength with which the electrons are attracted by the positive ions and is given by

$$P = \frac{mV_0ba}{\hbar^2}$$

where $m \rightarrow$ mass of the electron

$a, b \rightarrow$ limits within which the electron is assumed to move

$\hbar = \frac{h}{2\pi}$ [$h \rightarrow$ [Plancks constant]

15. *What is meant by Brillouin zone? Draw the same for an electron in a one dimensional mono-atomic lattice.*

Brillouin zones are the boundaries that are marked by the values of propagation vector $\vec{k}$ in which the electrons can have allowed energy values without diffraction.

Brillouin zone for an electron in a one dimensional mono-atomic lattice as shown in *Fig. 1(c)*

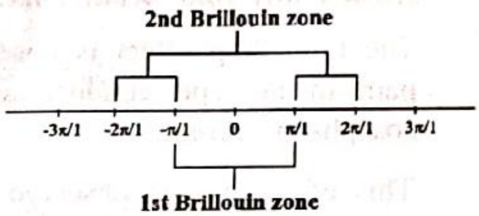


Fig. 1(c)

16. *Will the effective mass of the electron be negative? Justify your answer.*

Yes, the effective mass of the electron can also have a negative value.

Justification: The effective mass of the electron is the mass of the electron when it is accelerated in a periodic potential and is given by

$$m^* = \frac{\hbar^2}{d^2E/dk^2}$$

Here $\frac{d^2E}{dk^2}$ can vary from positive to negative value, therefore if d^2E/dk^2 is negative, then m^* will also have negative value. Also, this negative effective mass of an electron leads to the concept of hole.

Physically speaking the electrons with negative mass has same positive mass as that an electron but it has positive charge rather than negative charge.

17. Explain the concept of hole and give its advantage.

When the electrons are accelerated in a periodic potential, its mass varies and it moves in the direction opposite to the direction of the applied field. This variation of mass of an electron is called as negative mass behaviour of electrons.

Hole: The electrons with negative mass is called as hole, which has same positive mass as that an electron but instead of negative charge, the hole will posses positive charge.

Advantage: If we have 'n' number of empty states in a nearly filled band, then these 'n' number of empty states can be considered as 'n' number of holes.

18. What are the phenomenon that explains the concept of hole?

There are two phenomenon which explains the concept of hole *viz.*

(i) Hall effect

(ii) Thomson effect.

19. What is meant by effective mass approximation?

For an electron moving in a constant potential field $m^* = m$. But for an electron moving in a periodic potential $m^* \neq m$. Thus, when an electron moves in a periodic potential the free electron mass 'm' should be replaced by the effective mass m^* and this process is called as effective mass approximation.

20. What is f_k of an electron? Distinguish between conductors, semiconductors and insulators on the basis of f_k.

f_k represents the degree of freedom of an electron, which is the measure of the extent upto which an electron can remain free in the given energy state.

It is given by $f_k = \frac{m}{m^*}$

where $m \rightarrow$ free electron mass

$m^* \rightarrow$ effective mass of an electron

For conductors $m = m^*$ (ie.) $f_k = 1$, (i.e.,) we have more number of free electrons.

For semiconductors $m \neq m^*$. $\therefore f_k \neq 1$.

21. Compare free electron approximation and tight binding approximation.

Sl.No.	Free electron approximation	Tight binding approximation
1.	The potential energy of the electron is assumed to be lesser than its total energy.	The potential energy of the electrons is nearly equal to the total energy.
2.	The width of the forbidden bands (E_g) are smaller than the allowed bands.	The width of the forbidden bands (E_g) are larger than the allowed bands.
3.	The interaction between the neighbouring atoms will be very strong.	The interactions between the neighbouring atoms will be weak.
4.	As the atoms are closer to each other, the inter atomic distance decreases and hence the wave functions overlap with each other.	As the atoms are not closer, the interatomic distance increases and hence the wave functions will not overlap

1. *On the basis of spin how the materials are classified as para, ferro, antiferro and ferri magnetic.* **(Nov. 2002) (Nov. 2003, June 2009, June 2010)**

(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) Ferrimagnetic materials have spins in antiparallel manner but with unequal magnitudes.

2. *Give Curie-Weiss law and its importance.* **(May 2003)**

Curie-Weiss law is given by

$$\chi_m = \frac{C}{T-\theta}$$

where $C \rightarrow$ Curie constant

$T \rightarrow$ Absolute temperature

$\theta \rightarrow$ Curie temperature

Importance: It determines the susceptibility of the magnetic materials in terms of temperatures (i.e.,) If the temperature is less than Curie temperature, a paramagnetic material becomes diamagnetic and if the temperature is greater than Curie temperature, a ferromagnetic material becomes paramagnetic material.

3. ***What do you understand by the term, "magnetic domains" and "domain walls"?*** **(Nov 2002, 2003)**

Magnetic domains are the small regions in a ferromagnetic material which has a group of atoms. These atoms can be completely magnetised by favourable exchange spin-spin interaction. The walls of these small regions (or) domains are called domain walls.

4. ***Draw hysteresis loop and show the retentivity and co-ercivity in it.*** **(Nov. 2003)**

The hysteresis loop, retentivity and co-ercivity is shown in fig. 3(a).

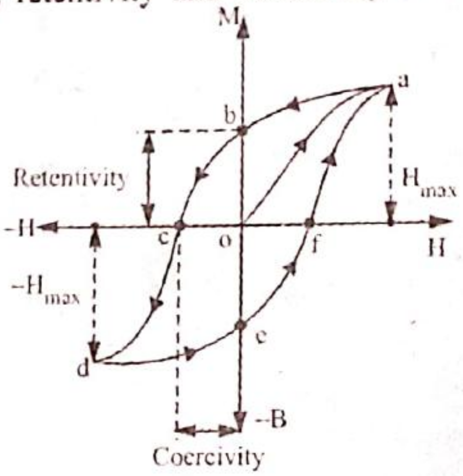
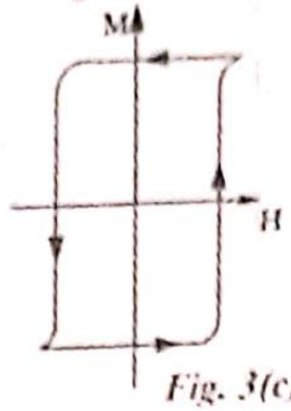


Fig. 3(a)

5. ***What are soft and hard magnetic materials? (or) Compare soft and hard magnetic materials on basis of Hysteresis loop. give examples.***

(April 2002, Nov. 2002, 2003, Nov. 2005, June 2009, Dec. 2009, June 2010, May 2011)

S.No.	Soft	Hard
1.	They can be easily magnetised and demagnetised.	They cannot be easily magnetised (or) demagnetised.
2.	Movement of domain wall is easy and hence even for a small applied field large magnetisation occurs.	Movement of domain wall is not easy due to the presence of impurities and hence large field is required for magnetisation.

S.No.	Soft	Hard
3.	The Hysteresis loop is very steep as shown in figure (3b).  *Fig. 3(b)*	The Hysteresis loop is very broad as shown in figure (3c).  *Fig. 3(c)*
4.	Loop area is less and hence the hysteresis loss is minimum.	The loop area is large and hence the hysteresis loss is maximum.
5.	Examples, Iron, silicon alloys, Ferrites, Garnets etc.	Carbon steel, Tungsten steel, Chromium steel, Cu-Ni-Fe (Cunife) Cu-Ni-Co (Cunico) Al-Ni-Co (Alnico)

6. What is domain theory of ferromagnetism? **(Dec. 2009)**

The group of atomic dipoles organized into tiny bounded regions in the ferromagnetic materials are called magnetic domains. The boundaries separating domains are called domain walls. In Ferro-magnets, when external magnetic field is applied, the domains align and results in large net magnetization.

7. Define magnetic lines of force and magnetic lines of induction. **(May 2011)**

Magnetic lines of force: It is defined as the continuous curve in a magnetic field which travels externally in the magnet from north pole to south pole.

Magnetic lines of induction: It is the imaginary lines of forces which are supposed to travel from south pole to north pole inside the magnet.

8. Discuss the orientation of spin for dia, para and ferro-magnetic substances. **(June 2009)**

Diamagnetic materials: Here the electron spins are randomly oriented and mostly they have equal and opposite spins. Thus the net magnetic moment is zero.

Paramagnetic material: Here the spins of electrons will not be equal, which leads to have some unpaired electrons. Hence there exists some resultant magnetic moment. Therefore in paramagnetic material the net magnetic moment is **not zero.**

Ferromagnetic material: In ferro magnetic materials the number of unpaired electrons will be more. Hence there exists a large resultant magnetic moment in it.

9. Classify the magnetic materials based on their magnetic moments.
(June 2009, June 2011)

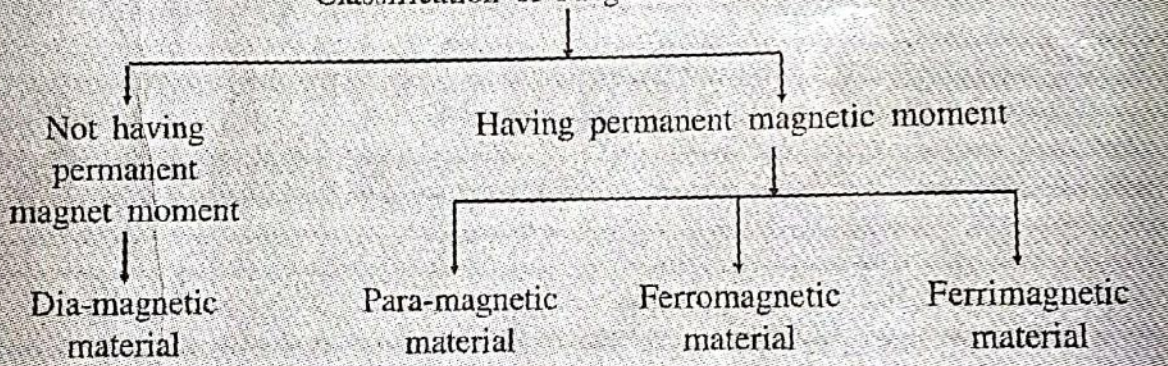
The magnetic materials can be classified into two major categories based on the presence of magnetic moments as follows.

Magnetic materials are classified according to the presence or absence of the permanent magnetic dipoles. Generally, every two electrons in an energy state of an atom will form a pair with opposite spins. Thus the resultant spin *magnetic moment is zero.* Hence they don't have permanent magnetic moments and they are called as *diamagnetic materials.* Examples. gold, germanium, silicon, etc.

But in some magnetic materials like iron, cobalt, etc., there exists unpaired electrons. The spin magnetic moment of these unpaired electrons interact with the adjacent atom's unpaired electron spin magnetic moment in a parallel manner resulting in *enormous permanent spin magnetic moment.* These materials are classified into *paramagnetic, ferromagnetic and ferrimagnetic materials* with respect to the electron spins.

(OR)

Classification of Magnetic materials



10. What are the four types of energies involves in the growth of magnetic domains?
(June 2009)

The four types of energies involved in the growth of magnetic domains are

(i) Exchange energy (or) magneto-static energy.

(ii) Anisotropy energy

(iii) Domain wall energy and

(iv) Magneto-strictive energy.

11. Define Hysteresis. What is meant by Hysteresis loop and what do you infer from it?
(May 2009, May 2011)

When a ferromagnetic material is made to undergo a cycle of magnetistion, the intensity of magnetisation (*I*) and the magnetic flux density (*B*) lags behind the applied magnetic field (*H*), and this process is known as Hysteresis.

The closed curve obtained during the cycle of magnetisation of a material is known as hysteresis loop.

Inference: The area of the loop gives the energy loss (or) hysteresis loss during the cycle of magnetisation.

12. *Define Bohr magneton.* **(June 2009, June 2010, May 2011)**

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

$$1 \text{ Bohr Magneton} = \frac{e\hbar}{2m} \Rightarrow \mu_B \Rightarrow 9.27 \times 10^{-24} \text{ Am}^2$$

13. *What are the required magnetic parameters for recording?* **(Nov. 2003)**

The basic parameters required for recording are

(i) Electromagnetic induction should occur in materials.

(ii) The material should easily acquire magnetism.

(iii) It should posses magneto-resistance i.e., the electrical resistance should vary with respect to the magnetisation.

(iv) Soft magnets should be used for temporary storage and hard magnets should be used for permanent storage.

ADDITIONAL PART 'A' QUESTIONS & ANSWERS

1. *What is meant by magnetic materials? Give examples.*

Magnetic materials are the materials which can be easily magnetised by keeping it in an external magnetic field.

Examples: Iron, Ferrites, Carbon steel etc.

2. *Define magnetic flux density and magnetic dipole with its unit.*

Magnetic flux density (*B*): It is defined as the number of magnetic lines of forces (ϕ_m) passing normally through unit area of cross section (A).

$$\text{(i.e.,) } B = \frac{\phi_m}{A} \text{ Wbm}^{-2} \text{ (or) Tesla}$$

Magnetic dipole: Two opposite magnetic poles separated by some distance is called magnetic dipole. It can be also be defined as the product of magnetic pole strength (m) and the length of the magnet. (i.e.,) $M_\mu = ml \text{ Wbm}^{-1}$

3. Define magnetic field intensity and intensity of magnetisation with its unit.

Magnetic field intensity (H): It is defined as the force experienced by a unit north pole placed at the given point in a magnetic field.

$$\text{(i.e.,)}\ H = \frac{F}{m}\ \text{Am}^{-1}$$

Intensity of magnetisation [M (or) I]: It is defined as the magnetic moment per unit volume.

$$\text{(i.e.,)}\ I = \frac{M_\mu}{V}\ \text{Wbm}^{-2}$$

4. Define magnetic susceptibility and magnetic permeability.

Magnetic susceptibility (χ_m): It is defined as the ratio between intensity of magnetisation (M (or) I) and the magnetic field intensity (H)

$$\text{(i.e.,)}\ \chi_m = \frac{I}{H}$$

Magnetic permeability (μ): It is defined as the ratio between the magnetic flux density (B) and the magnetic field intensity (H)

$$\text{(i.e.,)}\ \mu = \frac{B}{H}$$

5. Prove $\mu_r = 1 + \chi_m$

When a magnetic material is kept in an external magnetic field, then flux density can be written as

$$B = \mu_o(H + I) \quad \text{... (1)}$$

We know $\mu = \frac{B}{H} \Rightarrow B = \mu H$ ... (2)

Equating (1) and (2) we get $\mu H = \mu_o(H + I)$

(or) $$\mu_o \mu_r H = \mu_o H\left[1 + \frac{I}{H}\right] \quad \left[\because \mu = \mu_o \mu_r\right]$$

(or) $$\mu_r = \left[1 + \frac{I}{H}\right]$$

(or) $$\mu_r = 1 + \chi_m$$ Hence Proved $\left[\because \chi_m = \frac{I}{H}\right]$

6. Explain the term remanence and coercivity with its units.

Remanence/Retentivity: It is the residual intensity of magnetisation retained by the specimen even when the external magnetic field is cutoff.

Unit: Wbm^{-2}

Coercity: It is the strength of reverse magnetic field required to completely remove the residual magnetisation (or) demagnetise the material.

Unit: $\frac{\text{Ampere turn}}{\text{metre}}$

7. What is the origin of the presence of magnetic moments in magnetic materials?

The origin of presence of magnetic moments is due to orbital and spin motion of electrons in atom. Generally, every two electrons in an energy state of an atom will form a pair of opposite spins, but in some materials there exists unpaired electron spins also. These gives rise to a resultant spin magnetic moment, which plays a vital role in the classification of magnetic materials.

8. Why diamagnetic materials are called weak magnets and ferromagnetic materials are called strong magnets?

Weak magnets: If a diamagnetic material is kept in an external magnetic field, the electrons spins in the material reorient in such a way that they align perpendicular to the field direction and hence the materials will not be easily magnetised. Thus diamagnetic materials are called weak magnets.

Strong magnets: When a ferro magnetic material is kept in an external magnetic field, the electrons which are already aligned parallel to the direction of magnetic field acquires a very strong magnetic moment in it. Hence ferromagnetic materials are called strong magnets.

9. What is Curie temperature?

Curie temperature is the critical temperature below which a material can behaves as ferromagnetic material and above which it can behave as paramagnetic material.

UNIT 2

10. Compare the properties of dia, para and ferro magnetic materials.

S.No.	Dia-magnetic material	Para-magnetic material	Ferro-magnetic material
1.	The susceptibility is negative ($\chi = -ve$).	The susceptibility is positive and small ($\chi = +ve$)	The susceptibility is positive and large ($\chi = +ve$)
2.	The susceptibility is independent of temperature.	The susceptibility varies inversely with the absolute temperature.	The susceptibility depends upon the temperature.
3.	Permeability is less than 1.	Permeability is greater than 1.	Permeability is very much greater than 1.
4.	When the temperature is less than critical temperature, the diamagnetism suddenly disappears and becomes a normal material.	When the temperature of the material is less than Curie temperature, the para-magnetic material converted into diamagnetic material.	When the temperature is greater than Curie temperature, the ferromagnetic material is converted into paramagnetic material.
5.	**Examples:** Gold, antimony, bismuth, water, hydrogen, alcohol, germanium, silicon etc.	**Examples:** Platinum, chromium, aluminium, copper sulphate, manganese sulphate etc.	**Examples:** Iron, nickel, cobalt, steel, etc.

11. Define spontaneous magnetisation and discuss the same at low and high temperatures.

The molecular magnets in ferromagnetic materials are aligned in such a way that they exhibit a magnetisation even in the absence of an external magnetic field. This phenomenon is known as spontaneous magnetisation.

At low temperatures the spontaneous magnetisation is high and at high temperatures the spontaneous magnetisation becomes zero.

12. Discuss the effect of external magnetic field over magnetic domains.

When an external magnetic field is applied to the ferro magnetic materials, based on the strength of the fields, two process occurs. *viz*

(i) Movement of domain walls take place at weak magnetic field and

(ii) Rotation of domain walls take place at strong magnetic field.

13. What is meant by magneto-static energy and magneto-strictive energy?

Magneto-static energy: The interaction energy which makes the adjacent dipoles to align themselves is known as magneto-static energy. Since this energy is in the form of potential energy it is called magneto-static energy.

Magneto-strictive energy: When the domains are magnetised, there exists an expansion (or) shrinkage in domains, which inturn produces deformation in the materials. The energy produced in this effect is called magneto-strictive energy and these materials are termed as magneto-strictive materials.

14. What is meant by reversible and irreversible domains?

When the external magnetic field applied to a domain is increased, it starts expanding. Now when the external magnetic field is removed, if the domain returns to its original position it is called reversible domains and if the domain doesn't returns to its original position it is known as irreversible domains.

15. Distinguish the properties of soft and hard magnetic materials.

S.No.	Soft	Hard
1.	They can be easily magnetised and demagnetised.	They cannot be easily magnetised (or) demagnetised.
2.	Loop area is less and hence the hysteresis loss is minimum.	The loop area is large and hence the hysteresis loss is maximum.
3.	Susceptibility and permeability is high	Susceptibility and permeability is low.
4.	Retentivity and Coercivity are small	Retentivity and Coercivity are large.
5.	They have low eddy current loss.	They have high eddy current loss.
6.	These materials are free from irregularities like strain or impurities.	These materials have large amount of impurities and lattice defects.

16. What are the requirements (required properties) of a transformer core material and electromagnets?

(I) A **transformer core** material should have the following requirements (properties)

(i) High resistivity

(ii) Low eddy current losses

(II) An **electromagnet** should have the following requirements (properties)

(i) High initial permeability

(ii) Low coercivity.

UNIT 2

17. What is meant by eddy current and eddy current losses?

When an alternating magnetic field is applied to the material, it induces an e.m.f and sets up a large current in the material. This current is known as eddy current and the power loss is called eddy current losses.

18. What is meant by Garnet? Give examples.

Garnet is a ferrimagnetic material with a typical formula $Me_3Fe_5O_{12}$

where, $Me_3 \rightarrow$ Trivalent metal ion

$Fe_5 \rightarrow$ Trivalent ferric ion

Examples: Gadolinium Gallium Garnet, Yttrium Iron Garnet.

Properties

(i) They have high resistivity

(ii) They have low hysteresis loss

19. What is GMR?

If the charge in electrical resistance is very high compared to the magnetisation, it is called as Giant Magneto-Resistance (GMR) and this effect is called GMR effect.

20. What are ESD magnets? Give its properties.

ESD magnets are Elongated Single Domain magnets, which are made by very small particles with very high magnetisation. Hence these ESD magnets possess the following properties

Properties

(i) They are highly stable.

(ii) They have single domain structure.

(iii) They possess large magnetisation.

21. What is meant by Magnetic HDD? Give the principle of storing data in HDD.

Hard disk drives [HDD] made up of magnetic garnet materials are called ***magnetic hard disk drives***. It is a mass data storage device recently used for storing data to a very high level in terms of Tera bytes.

Now-a-days GMR [Giant Magneto Resistive] sensors, which has a very high magnetic sensitivity are used to read the data at greater speed.

Principle

In Hard disk drives, the binary data in terms of zero's (0) and one's (1) are stored by inducing magnetic moment in a thin magnetic layer and GMR effect is used as the principle to read the data in HDD.

Here ***zero(0) represents missing transition*** and ***one (1) represents transition in the medium.***

22. What are the advantages and disadvantages of HDD?

Advantages

1. HDD's can store data interms of Terabytes and in future it can store data interms of Petabytes and Exabytes.
2. It is has very large storage capacity.
3. It is compact in size and can be easily transferred from one place to another.
4. The size of the recording medium in HDD shall be reduced upto few nano-metres using nanotechnology.
5. GMR sensors are non diffusive and are very sensitive in reading.

Disadvantages

1. HDD is slower than SSD [solid state drives].
2. They consume more power and will damage, when dropped even at a smaller distance.
3. Sometimes the data in HDD may be corrupted, due to thermal radiation.
4. HDD has bulkier form factor.
5. The GMR noise ratio is high for the nano size recording media as it is temperature dependent.

23. Whatis the role of GMR sensor in Magnetic HDD

1. Giant magnetoresistive (GMR) effect is the principle used to read/retrieve the data from the recording medium.
2. When the GMR sensor is made to move near the recorded medium, then, the resistance of the GMR sensor varies, with respect to the orientation of the magnetic moments as follows.
3. ***When the layers are magnetised in parallel manner****, then the resistance in the GMR sensor is minimum and therefore maximum current flows through the sensor,* ***which represents the data as one (1)****, as shown in* ***Fig. 3(f).***
4. ***When the layers are magnetised in antiparallel manner****, then the resistance in the GMR sensor will be maximum and therefore minimum (or) no current*

1. *Define electrical conductivity.* **(April 2002)**

The electrical conductivity is defined as the quantity of electricity flowing per unit area per unit time maintained at unit potential gradient.

Unit: $\Omega^{-1} M^{-1}$

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

where $n \rightarrow$ Number of free electrons per unit volume

$e \rightarrow$ charge of an electron

$\tau \rightarrow$ Relaxation time

$m \rightarrow$ mass of an electron

2. *Define Mobility of Electrons.* **(April 2003, June 2009)**

When electric field (E) is applied to metals, the electrons moves in the direction opposite to the field direction with the velocity 'v', then mobility of an electron is defined as the velocity acquired by the electron per unit electric field (E).

$$\text{(i.e.) } \mu = \frac{v}{E}$$

3. ***Give the postulates of free electron theory.*** **(June 2009, May 2011)**

(i) The free electrons in the metal moves freely, similar to the gas molecules moving in a vessel and it obeys the classical kinetic theory of gases.

(ii) These free electrons moves in a constant potential field due to ions fixed in the lattice.

(iii) When field is applied the free electron moves in the direction opposite to that of the field direction.

(iv) Due to field applied, they acquire a velocity called drift velocity and the electron velocities in the metal obeys the Maxwell-Boltzmann statistics.

4. ***Define Drift velocity and give its formula.*** **(June 2010, June 2011)**

Drift velocity is defined as the average velocity acquired by the free electron in a particular direction, due to the application of electric field and is denoted by the letter v_d

Formula: $v_d = \frac{e \tau_c E}{m}$

where $e \rightarrow$ charge of the electron

$\tau_c \rightarrow$ mean collision time

$E \rightarrow$ field applied

$m \rightarrow$ mass of the electron

5. ***Distinguish between relaxation time and collision time.*** **(June 2009)**

S.No.	Relaxation Time (τ)	Collision time (τ_c)
1.	It is the time taken by the free electron to reach its equilibrium position from its disturbed position, due to the field applied.	It is the average time taken by a free electron between two successive collision.
2.	$\tau = 10^{-14}$ seconds (Approx)	$\tau_c = \lambda / \bar{c}$ where $\lambda \rightarrow$ mean free path $\bar{c} \rightarrow$ Root mean square velocity

6. ***Define mean free path.*** **(June 2009, June 2012)**

The average distance travelled between two successive collisions is called mean free path. It is denoted by the letter 'λ'.

Mean free path $\lambda = \bar{c}\, \tau_c$

where $\bar{c} \rightarrow$ Root mean square velocity of the electron

$\tau_c \rightarrow$ Collision time

UNIT 2

7. Mention any two important features of quantum free electron theory of metals. **(April 2003)**

(i) It shows that the energy levels of an electron are discrete

(ii) The Maximum energy level upto which the electrons can be filled is denoted by Fermi energy level.

8. Get the microscopic form of Ohm's law and state whether it is true for all temperatures? **(June 2009)**

According to classical free electron theory current density

$$J = \sigma E$$

where $\sigma \rightarrow$ electrical conductivity

since conductivity $(\sigma) = \frac{1}{\text{Resistivity } (\rho)}$, we can write

$$E = J\rho$$

For a conductor of length 'l' and area of cross section 'A'

Resistance $= \frac{\rho l}{A}$

$\therefore$ Voltage $V = I \frac{\rho l}{A}$

(or) $V = IR$

$\therefore$ Microscopically we can write $V = IR$ as $E = J\rho$

Since the resistivity varies with respect to the temperature, the microscopic form of Ohm's law is not true for all the temperatures.

9. What are the source of resistance in metals? **(Nov. 2003)**

The resistance in metals is due to

(i) Impurities present in the metals

(ii) Temperature of the metal

(iii) Number of free electrons

10. Define Wiedemann-Franz law. Give the value of Lorentz number and state whether it holds good for all metals and at all temperatures?

(June 2007, June 2009, Dec. 2009, June 2010, May 2011)

Wiedemann-Franz law is defined as, "the ratio between the thermal conductivity (K) and the electrical conductivity (σ) of a metal is directly proportional to the absolute temperature (T) of the metal".

11. *What are the drawbacks of classical free electron theory*
(June 2005, June 2007, June 2009, June 2010, May 2011)

(i) It is a macroscopic theory

(ii) Classical theory states that all free electrons will absorb energy, but quantum theory states that only few electrons will absorb energy.

(iii) This theory cannot explain the Compton, photo-electric effect, paramagnetism, ferromagnetism, etc.

(iv) The theoretical and experimental values of specific heat and electronic specific heat is not matched.

(v) By classical theory $\frac{K}{\sigma T}$ = constant for all temperatures, but by Quantum theory $\frac{K}{\sigma T} \neq$ constant for all temperatures.

(vi) The Lorentz number by classical theory does not have good agreement with the experimental value and is rectified by quantum theory.

UNIT 2

12. *Define Fermi energy level and Fermi energy with its importance.*
(Nov. 2002, Nov 2005, June 2007, June 2009, June 2010, May 2011, June 2012)

Fermi energy level: It is the highest reference energy level of a particle at absolute zero. It is the state at which the probability of electron occupation is 50% at any temperature.

Importance: It is the reference energy level which separates the filled energy levels and vacant energy levels.

Fermienergy (E_F): It is the maximum energy of the quantum state corresponding to Fermi energy level at absolute zero. It is also the energy of thestate at which the probability of electron occupation is 50% at any temperature.

Importance: Fermi energy determines the energy of the particle at any temperature.

13. *Write the Fermi-dirac distribution function and give its importance.*
(April 2003, Nov. 2003, Dec. 2003, June 2010, May 2011)

Fermi function F(E): Fermi-dirac distribution function represents the probability of an electron occupying a given energy level. It is given by

$$F(E) = \frac{1}{1 + e^{(E - E_F)/K_B T}}$$

where $K_B \rightarrow$ Boltzmann constant

$T \rightarrow$ Absolute Temperature

Importance: It gives the probability of filling the electron within the Fermi energy level.

For example if $F(E) = 0.7$ means, there is 70% chance for filling an electron within the Fermi energy level.

14. *Draw the Fermi distribution curve at OK and at any temperature TK. (or) How does the Fermi function varies with temperature?*
(Nov. 2003, June 2009, Dec. 2009, June 2010, May 2011)

The Fermi function varies with respect to the temperature as shown in *Fig. 1(a)* Here at 0 K all the energy states below E_{F_0} are filled and all those above it are empty. Now when the temperature is increased, the electron takes an energy K_BT and hence the Fermi function falls to zero.

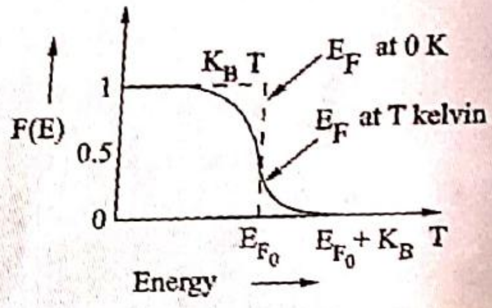


Fig. 1(a)

15. *What is meant by Fermi energy of a metal?* **(April 2002, Nov. 2002)**

Fermi energy is the energy of the quantum state corresponding to the Fermi energy level at absolute zero.

It is the maximum energy that an electron in a metal can possess at absolute zero.

16. *Define density of states and given an example and state its importance.*
(Dec. 2003)

Define density of states and sketch the same for a metal.
(May 2008, June 2010, May 2011)

Definition: Density of states $Z(E)dE$ is defined as the number of available energy states per unit volume in an energy interval dE.

Example

We can say the density of states of a cubical metal piece ([*Fig. 1(b)*] as

$$Z(E)\,dE = \frac{\text{Number of available energy states between } E \text{ and } E + dE \text{ in a cubical metal piece}}{\text{Volume of that cubical metal piece}}$$

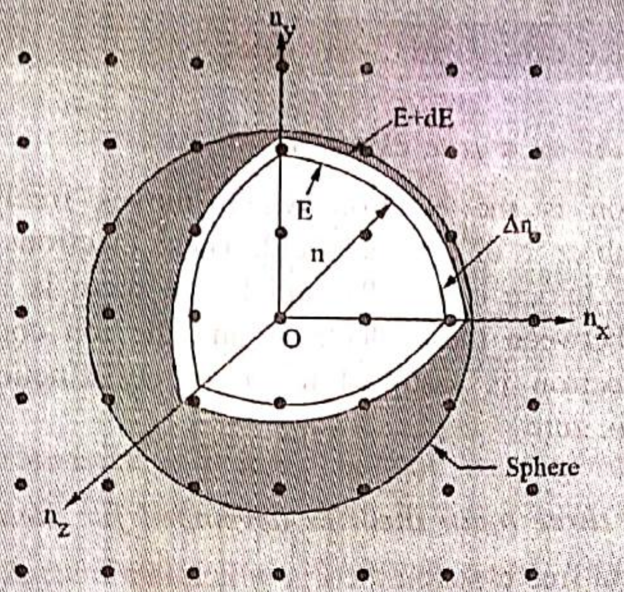


Fig. 1(b)

Importance: It is used to calculate the number of charge carriers per unit volume of any solid.

17. Write a note on effective mass of an electron moving in a periodic potential. (Nov. 2003)

Definition:

Effective mass of an electron is the mass of the electron when it is accelerated in a periodic potential and is denoted by m^*

Explanation:

We know mass of an electron is constant, but it is found to vary, when it is accelerated in a periodic potential and this varying mass is called as effective mass, given by

$$m^* = \frac{\hbar^2}{d^2E/dk^2}$$

The effective mass depends on the value of $\frac{d^2E}{dk^2}$ (ie)

(i) If $\frac{d^2E}{dk^2}$ is positive; m^* is also positive

(ii) If $\frac{d^2E}{dk^2}$ is negative; m^* is negative

(iii) If $\frac{d^2E}{dk^2}$ is zero; m^* becomes infinite.

Mostly $m^* = m$ for metals and $m^* \neq m$ for semiconductors and insulators.

ADDITIONAL PART-A QUESTIONS & ANSWERS

1. *What is meant by a free electron?*

Free electron is the electron which moves freely (or) randomly in all directions in the absence of external field. These electrons collides with each other and also with the lattice elastically and hence there is no loss in energy. Also, since the forces between these electrons and the ion core is neglected, the total energy of the electron is assumed to be purely kinetic energy and hence the potential energy is zero.

2. *List out the three main theories developed for metals.*

(i) Classical free electron theory, which is a macroscopic theory and it obeys classical laws.

(ii) Quantum free electron theory, which is a microscopic theory and it obeys quantum laws.

(iii) Zone theory (or) band theory is also a microscopic theory which is based on the energy bands of solids.

3. *What are the differences between Drift velocity and thermal velocity of an electron.*

S.No.	Drift velocity	Thermal velocity
1.	Drift velocity is the average velocity acquired by the free electron, in the presence of electric field.	Thermal velocity is the velocity of an electron without any external field.
2.	The electrons moving with drift velocity moves in the direction opposite to that of the field direction	The direction of the electrons moving with thermal velocity is random
3.	The velocity is very less, say in the order of 0.5 m/s	The velocity is very high, say in the order of 10^5 m/s

4. *Distinguish between electrical conductivity and thermal conductivity.*

S.No.	Electrical Conductivity	Thermal Conductivity
1.	The Co-efficient of electrical conductivity is defined as the quantity of ***electricity flowing*** per unit area per unit time maintained at unit potential gradient.	The Co-efficient of Thermal conductivity is defined as the quantity of ***heat conducted*** per unit area per unit time maintained at unit temperature gradient.
2.	Electrical conductivity is purely due to number of free electrons.	Thermal conductivity is due to both free electrons and phonons.
3.	Conduction of electricity takes place from higher potential end to the lower potential end.	Conduction of heat takes place from hot end to cold end.
4.	**Unit:** $ohm^{-1}\ m^{-1}$	**Unit:** $Wm^{-1}\ K^{-1}$

5. *What are the similarities between electrical and thermal conductivity of metals?*

1. The electrical and thermal conductivity decreases with the increase in temperature and impurities.
2. The electrical and thermal conductivity is very high at low temperature.
3. For non-metals, the electrical and thermal conductivity is very less.

6. *What are the success of classical free electron theory.*

(i) It verifies Ohms law.

(ii) It explains the electrical and thermal conductivity of metals.

(iii) It is used to derive Wiedemann - Franz law.

(iv) The optical properties of metals can be explained using this theory.

7. *Discuss the variation of resistivity of a conductor with respect to temperatures.*

The variation of resistivity with respect to temperature can be explained as follows.

(i) The resistivity of a conductor remains almost constant at lower temperatures. ($\rho = \text{constant}$)

(ii) The resistivity is proportional to T^5 i.e., $\rho \propto T^5$ from low temperature to the Debye temperature.

(iii) The resistivity is directly proportional to T i.e., $\rho \propto T$, above Debye Temperature.

8. *What is meant by degenerate and non-degenerate states.*

(i) Degeneracy: *It is seen from equation (28) and equation (29), for several combination of quantum numbers we have same energy eigen value but different eigen functions. Such states and energy levels are called **Degenerate State.***

The three combination of quantum numbers (112), (121) and (211), which gives same eigen value but different eigen functions are called **3 fold degenerate state.**

(ii) Non-Degeneracy: *For various combinations of quantum number if we have same energy eigen value and same (one) eigen function then such states and energy levels are called **Non-Degenerate State.***

Example

For $n_x = 2\ n_y = 2\ n_z = 2$ we have $E_{222} = \frac{12\,h^2}{8ma^2}$ and

$$\psi_{222} = \sqrt{\frac{8}{a^3}}\ \sin\frac{2\pi x}{a}\ \sin\frac{2\pi y}{a}\ \sin\frac{2\pi z}{a}$$

9. *What are the differences between quantum theory and zone theory?*

S.No.	Quantum theory	Zone theory
1.	Here the electron is assumed to move in a region of constant potential.	In zone theory the electron is assumed to move in a region of periodic potential
2.	According to this theory the mass of the electron remains constant, when it moves through constant potential	Accordingly to zone theory the mass of the electron varies when it moves through periodic potential and is called effective mass of an electron.
3.	If fails to explain why some solids behaves as conductors, some behave as insulators and semi conductors.	It explains the behaviour of solids as conductors, semiconductors and insulators

10. *Define zero probability, unit probability and fractional probability.*

Zero probability: It is the state which remains always empty and the electrons cannot be filled in it, i.e., $F(E) = 0$

Unit probability: It is the state which is always filled with the electrons, i.e., $F(E) = 1$

Fractional probability: It is the state which may be filled (or) empty (or) partially filled by electrons (or) it is the state which is filled by the electrons for some time and then will become empty, i.e., $F(E)$ will be a fraction like 0.5, 0.6 etc.

11. What is meant by tunnelling effect?

In quantum mechanics a particle having lesser energy (E) than the barrier potential (V) can easily cross over the potential barrier having a finite width 'l' even without climbing over the barrier by tunnelling through the barrier. This process is called Tunnelling.

12. Mention any four occurrences of tunnelling effect.

1. The tunnelling effect is observed in Josephson junction, in which electron pairs in the super conductors tunnel through the barrier layer, giving rise to Josephson current.
2. This effect is also observed in the case of emission of alpha particles by radioactive nuclei.
   Here, though the 'α' particle has very less kinetic energy they are able to escape from the nucleus whose potential wall is around 25 MeV high.
3. Tunnelling also occurs in certain semiconductor diodes called tunnel diodes.
4. Electron tunnels through insulating layer and act as a switch by tunnelling effect.

13. What do you understand by Fermi-dirac statistics and define fermions.

In the case of Fermi-dirac statistics the following points are considered.

(i) The particles (electrons) are indistinguishable.

(ii) The electrons which obey the Fermi-dirac statistics are called as ***fermions.***

(iii) Each energy state can have only one particle with one spin.

(iv) The number of energy states should be greater than (or) equal to number of particles, for example to fill say 9 particles, atleast 9 states should be available.

(v) There is no restriction in choosing the particle, (i.e) we can choose any particle to fill in any state.

(vi) The total energy of the system = Sum of all the energies of the particles.

UNIT 2

14. *Define scattering power of the potential barrier.*

Scattering power of a potential barrier is defined as the strength with which the electrons are attracted by the positive ions and is given by

$$P = \frac{mV_o ba}{\hbar^2}$$

where $m \rightarrow$ mass of the electron

$a, b \rightarrow$ limits within which the electron is assumed to move

$\hbar = \frac{h}{2\pi}$ [$h \rightarrow$ [Plancks constant]

15. *What is meant by Brillouin zone? Draw the same for an electron in a one dimensional mono-atomic lattice.*

Brillouin zones are the boundaries that are marked by the values of propagation vector $\vec{k}$ in which the electrons can have allowed energy values without diffraction.

Brillouin zone for an electron in a one dimensional mono-atomic lattice as shown in *Fig. 1(c)*

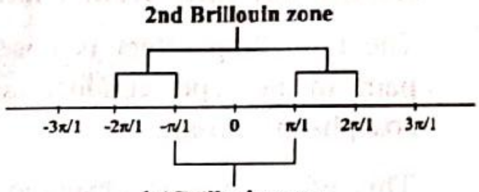


Fig. 1(c)

16. *Will the effective mass of the electron be negative? Justify your answer.*

Yes, the effective mass of the electron can also have a negative value.

Justification: The effective mass of the electron is the mass of the electron when it is accelerated in a periodic potential and is given by

$$m^* = \frac{\hbar^2}{d^2E/dk^2}$$

Here $\frac{d^2E}{dk^2}$ can vary from positive to negative value, therefore if d^2E/dk^2 is negative, then m^* will also have negative value. Also, this negative effective mass of an electron leads to the concept of hole.

Physically speaking the electrons with negative mass has same positive mass as that an electron but it has positive charge rather than negative charge.

17. Explain the concept of hole and give its advantage.

When the electrons are accelerated in a periodic potential, its mass varies and it moves in the direction opposite to the direction of the applied field. This variation of mass of an electron is called as negative mass behaviour of electrons.

Hole: The electrons with negative mass is called as hole, which has same positive mass as that an electron but instead of negative charge, the hole will posses positive charge.

Advantage: If we have 'n' number of empty states in a nearly filled band, then these 'n' number of empty states can be considered as 'n' number of holes.

18. What are the phenomenon that explains the concept of hole?

There are two phenomenon which explains the concept of hole *viz.*

(i) Hall effect

(ii) Thomson effect.

19. What is meant by effective mass approximation?

For an electron moving in a constant potential field $m^* = m$. But for an electron moving in a periodic potential $m^* \neq m$. Thus, when an electron moves in a periodic potential the free electron mass 'm' should be replaced by the effective mass m^* and this process is called as effective mass approximation.

20. What is f_k of an electron? Distinguish between conductors, semiconductors and insulators on the basis of f_k.

f_k represents the degree of freedom of an electron, which is the measure of the extent upto which an electron can remain free in the given energy state.

It is given by $f_k = \frac{m}{m^*}$

where $m \rightarrow$ free electron mass

$m^* \rightarrow$ effective mass of an electron

For conductors $m = m^*$ (ie.) $f_k = 1$, (i.e.,) we have more number of free electrons.

For semiconductors $m \neq m^*$. $\therefore f_k \neq 1$.

21. *Compare free electron approximation and tight binding approximation.*

Sl.No.	Free electron approximation	Tight binding approximation
1.	The potential energy of the electron is assumed to be lesser than its total energy.	The potential energy of the electrons is nearly equal to the total energy.
2.	The width of the forbidden bands (E_g) are smaller than the allowed bands.	The width of the forbidden bands (E_g) are larger than the allowed bands.
3.	The interaction between the neighbouring atoms will be very strong.	The interactions between the neighbouring atoms will be weak.
4.	As the atoms are closer to each other, the inter atomic distance decreases and hence the wave functions overlap with each other.	As the atoms are not closer, the interatomic distance increases and hence the wave functions will not overlap

1. ***On the basis of spin how the materials are classified as para, ferro, antiferro and ferri magnetic.*** **(Nov. 2002) (Nov. 2003, June 2009, June 2010)**

   (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) Ferrimagnetic materials have spins in antiparallel manner but with unequal magnitudes.

2. ***Give Curie-Weiss law and its importance.*** **(May 2003)**

   Curie-Weiss law is given by

$$\chi_m = \frac{C}{T - \theta}$$

where $C \rightarrow$ Curie constant

$T \rightarrow$ Absolute temperature

$\theta \rightarrow$ Curie temperature

Importance: It determines the susceptibility of the magnetic materials in terms of temperatures (i.e.,) If the temperature is less than Curie temperature, a paramagnetic material becomes diamagnetic and if the temperature is greater than Curie temperature, a ferromagnetic material becomes paramagnetic material.

3. ***What do you understand by the term, "magnetic domains" and "domain walls"?*** **(Nov 2002, 2003)**

Magnetic domains are the small regions in a ferromagnetic material which has a group of atoms. These atoms can be completely magnetised by favourable exchange spin-spin interaction. The walls of these small regions (or) domains are called domain walls.

4. ***Draw hysteresis loop and show the retentivity and co-ercivity in it.*** **(Nov. 2003)**

The hysteresis loop, retentivity and co-ercivity is shown in fig. 3(a).

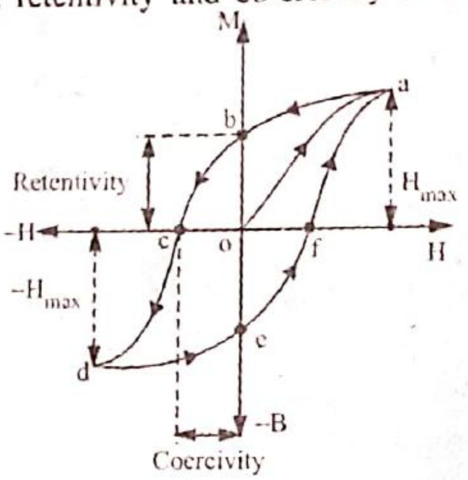
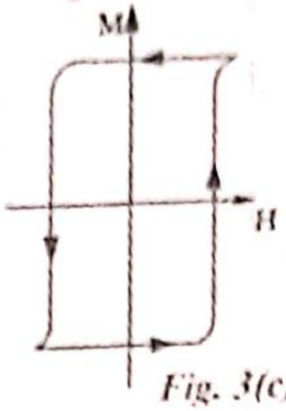


Fig. 3(a)

5. ***What are soft and hard magnetic materials? (or) Compare soft and hard magnetic materials on basis of Hysteresis loop. give examples.***

(April 2002, Nov. 2002, 2003, Nov. 2005, June 2009, Dec. 2009, June 2010, May 2011)

S.No.	Soft	Hard
1.	They can be easily magnetised and demagnetised.	They cannot be easily magnetised (or) demagnetised.
2.	Movement of domain wall is easy and hence even for a small applied field large magnetisation occurs.	Movement of domain wall is not easy due to the presence of impurities and hence large field is required for magnetisation.

S.No.	Soft	Hard
3.	The Hysteresis loop is very steep as shown in figure (3b).  *Fig. 3(b)*	The Hysteresis loop is very broad as shown in figure (3c).  *Fig. 3(c)*
4.	Loop area is less and hence the hysteresis loss is minimum.	The loop area is large and hence the hysteresis loss is maximum.
5.	Examples, Iron, silicon alloys, Ferrites, Garnets etc.	Carbon steel, Tungsten steel, Chromium steel, Cu-Ni-Fe (Cunife) Cu-Ni-Co (Cunico) Al-Ni-Co (Alnico)

6. What is domain theory of ferromagnetism? **(Dec. 2009)**

The group of atomic dipoles organized into tiny bounded regions in the ferromagnetic materials are called magnetic domains. The boundaries separating domains are called domain walls. In Ferro-magnets, when external magnetic field is applied, the domains align and results in large net magnetization.

7. Define magnetic lines of force and magnetic lines of induction. **(May 2011)**

Magnetic lines of force: It is defined as the continuous curve in a magnetic field which travels externally in the magnet from north pole to south pole.

Magnetic lines of induction: It is the imaginary lines of forces which are supposed to travel from south pole to north pole inside the magnet.

8. Discuss the orientation of spin for dia, para and ferro-magnetic substances. **(June 2009)**

Diamagnetic materials: Here the electron spins are randomly oriented and mostly they have equal and opposite spins. Thus the net magnetic moment is zero.

Paramagnetic material: Here the spins of electrons will not be equal, which leads to have some unpaired electrons. Hence there exists some resultant magnetic moment. Therefore in paramagnetic material the net magnetic moment is **not zero.**

Ferromagnetic material: In ferro magnetic materials the number of unpaired electrons will be more. Hence there exists a large resultant magnetic moment in it.

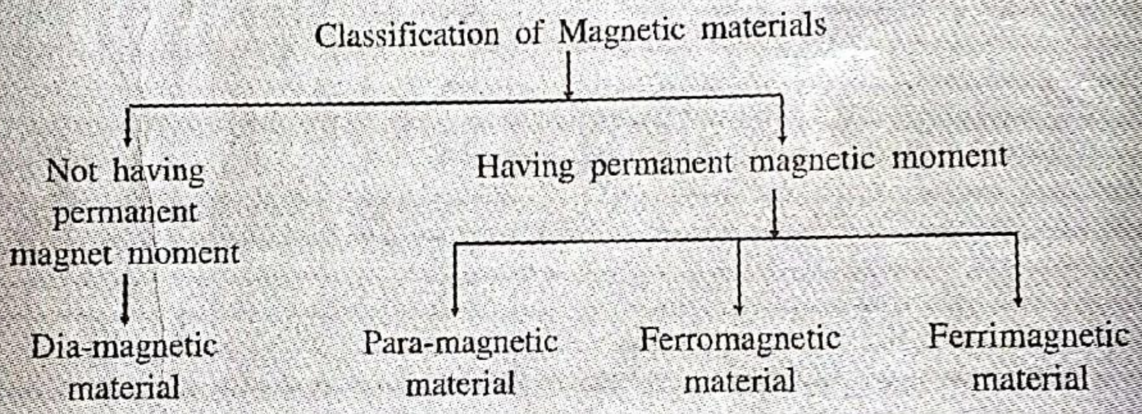
9. *Classify the magnetic materials based on their magnetic moments.*
(June 2009, June 2011)

The magnetic materials can be classified into two major categories based on the presence of magnetic moments as follows.

Magnetic materials are classified according to the presence or absence of the permanent magnetic dipoles. Generally, every two electrons in an energy state of an atom will form a pair with opposite spins. Thus the resultant spin *magnetic moment is zero.* Hence they don't have permanent magnetic moments and they are called as *diamagnetic materials.* Examples. gold, germanium, silicon, etc.

But in some magnetic materials like iron, cobalt, etc., there exists unpaired electrons. The spin magnetic moment of these unpaired electrons interact with the adjacent atom's unpaired electron spin magnetic moment in a parallel manner resulting in *enormous permanent spin magnetic moment.* These materials are classified into *paramagnetic, ferromagnetic and ferrimagnetic materials* with respect to the electron spins.

(OR)



10. *What are the four types of energies involves in the growth of magnetic domains?* **(June 2009)**

The four types of energies involved in the growth of magnetic domains are

(i) Exchange energy (or) magneto-static energy.
(ii) Anisotropy energy
(iii) Domain wall energy and
(iv) Magneto-strictive energy.

11. *Define Hysteresis. What is meant by Hysteresis loop and what do you infer from it?* **(May 2009, May 2011)**

When a ferromagnetic material is made to undergo a cycle of magnetistion, the intensity of magnetisation (*I*) and the magnetic flux density (*B*) lags behind the applied magnetic field (*H*), and this process is known as Hysteresis.

The closed curve obtained during the cycle of magnetisation of a material is known as hysteresis loop.

Inference: The area of the loop gives the energy loss (or) hysteresis loss during the cycle of magnetisation.

12. *Define Bohr magneton.* **(June 2009, June 2010, May 2011)**

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

$$1 \text{ Bohr Magneton} = \frac{e\hbar}{2m} \Rightarrow \mu_B \Rightarrow 9.27 \times 10^{-24} \text{ Am}^2$$

13. *What are the required magnetic parameters for recording?* **(Nov. 2003)**

The basic parameters required for recording are

(i) Electromagnetic induction should occur in materials.

(ii) The material should easily acquire magnetism.

(iii) It should posses magneto-resistance i.e., the electrical resistance should vary with respect to the magnetisation.

(iv) Soft magnets should be used for temporary storage and hard magnets should be used for permanent storage.

ADDITIONAL PART 'A' QUESTIONS & ANSWERS

1. *What is meant by magnetic materials? Give examples.*

Magnetic materials are the materials which can be easily magnetised by keeping it in an external magnetic field.

Examples: Iron, Ferrites, Carbon steel etc.

2. *Define magnetic flux density and magnetic dipole with its unit.*

Magnetic flux density (*B*): It is defined as the number of magnetic lines of forces (ϕ_m) passing normally through unit area of cross section (A).

$$\text{(i.e.,) } B = \frac{\phi_m}{A} \text{ Wbm}^{-2} \text{ (or) Tesla}$$

Magnetic dipole: Two opposite magnetic poles separated by some distance is called magnetic dipole. It can be also be defined as the product of magnetic pole strength (m) and the length of the magnet. (i.e.,) $M_\mu = ml \text{ Wbm}^{-1}$

3. *Define magnetic field intensity and intensity of magnetisation with its unit.*

Magnetic field intensity (H): It is defined as the force experienced by a unit north pole placed at the given point in a magnetic field.

$$\text{(i.e.,)}\ H = \frac{F}{m}\ \text{Am}^{-1}$$

Intensity of magnetisation [M (or) I]: It is defined as the magnetic moment per unit volume.

$$\text{(i.e.,)}\ I = \frac{M_\mu}{V}\ \text{Wbm}^{-2}$$

4. *Define magnetic susceptibility and magnetic permeability.*

Magnetic susceptibility (χ_m): It is defined as the ratio between intensity of magnetisation (M (or) I) and the magnetic field intensity (H)

$$\text{(i.e.,)}\ \chi_m = \frac{I}{H}$$

Magnetic permeability (μ): It is defined as the ratio between the magnetic flux density (B) and the magnetic field intensity (H)

$$\text{(i.e.,)}\ \mu = \frac{B}{H}$$

5. *Prove* $\mu_r = 1 + \chi_m$

When a magnetic material is kept in an external magnetic field, then flux density can be written as

$$B = \mu_o(H + I) \quad \text{... (1)}$$

We know $\mu = \frac{B}{H} \Rightarrow B = \mu H$ ... (2)

Equating (1) and (2) we get $\mu H = \mu_o(H + I)$

(or) $$\mu_o \mu_r H = \mu_o H\left[1 + \frac{I}{H}\right] \quad \left[\because \mu = \mu_o \mu_r\right]$$

(or) $$\mu_r = \left[1 + \frac{I}{H}\right]$$

(or) $$\boxed{\mu_r = 1 + \chi_m}$$ Hence Proved $\left[\because \chi_m = \frac{I}{H}\right]$

6. Explain the term remanence and coercivity with its units.

Remanence/Retentivity: It is the residual intensity of magnetisation retained by the specimen even when the external magnetic field is cutoff.

Unit: Wbm^{-2}

Coercity: It is the strength of reverse magnetic field required to completely remove the residual magnetisation (or) demagnetise the material.

Unit: $\frac{\text{Ampere turn}}{\text{metre}}$

7. What is the origin of the presence of magnetic moments in magnetic materials?

The origin of presence of magnetic moments is due to orbital and spin motion of electrons in atom. Generally, every two electrons in an energy state of an atom will form a pair of opposite spins, but in some materials there exists unpaired electron spins also. These gives rise to a resultant spin magnetic moment, which plays a vital role in the classification of magnetic materials.

8. Why diamagnetic materials are called weak magnets and ferromagnetic materials are called strong magnets?

Weak magnets: If a diamagnetic material is kept in an external magnetic field, the electrons spins in the material reorient in such a way that they align perpendicular to the field direction and hence the materials will not be easily magnetised. Thus diamagnetic materials are called weak magnets.

Strong magnets: When a ferro magnetic material is kept in an external magnetic field, the electrons which are already aligned parallel to the direction of magnetic field acquires a very strong magnetic moment in it. Hence ferromagnetic materials are called strong magnets.

9. What is Curie temperature?

Curie temperature is the critical temperature below which a material can behaves as ferromagnetic material and above which it can behave as paramagnetic material.

UNIT 2

UNIT 2

10. Compare the properties of dia, para and ferro magnetic materials.

S.No.	Dia-magnetic material	Para-magnetic material	Ferro-magnetic material
1.	The susceptibility is negative ($\chi = -ve$).	The susceptibility is positive and small ($\chi = +ve$)	The susceptibility is positive and large ($\chi = +ve$)
2.	The susceptibility is independent of temperature.	The susceptibility varies inversely with the absolute temperature.	The susceptibility depends upon the temperature.
3.	Permeability is less than 1.	Permeability is greater than 1.	Permeability is very much greater than 1.
4.	When the temperature is less than critical temperature, the diamagnetism suddenly disappears and becomes a normal material.	When the temperature of the material is less than Curie temperature, the para-magnetic material converted into diamagnetic material.	When the temperature is greater than Curie temperature, the ferromagnetic material is converted into paramagnetic material.
5.	**Examples:** Gold, antimony, bismuth, water, hydrogen, alcohol, germanium, silicon etc.	**Examples:** Platinum, chromium, aluminium, copper sulphate, manganese sulphate etc.	**Examples:** Iron, nickel, cobalt, steel, etc.

11. Define spontaneous magnetisation and discuss the same at low and high temperatures.

The molecular magnets in ferromagnetic materials are aligned in such a way that they exhibit a magnetisation even in the absence of an external magnetic field. This phenomenon is known as spontaneous magnetisation.

At low temperatures the spontaneous magnetisation is high and at high temperatures the spontaneous magnetisation becomes zero.

12. Discuss the effect of external magnetic field over magnetic domains.

When an external magnetic field is applied to the ferro magnetic materials, based on the strength of the fields, two process occurs. *viz*

(i) Movement of domain walls take place at weak magnetic field and

(ii) Rotation of domain walls take place at strong magnetic field.

13. What is meant by magneto-static energy and magneto-strictive energy?

Magneto-static energy: The interaction energy which makes the adjacent dipoles to align themselves is known as magneto-static energy. Since this energy is in the form of potential energy it is called magneto-static energy.

Magneto-strictive energy: When the domains are magnetised, there exists an expansion (or) shrinkage in domains, which inturn produces deformation in the materials. The energy produced in this effect is called magneto-strictive energy and these materials are termed as magneto-strictive materials.

14. What is meant by reversible and irreversible domains?

When the external magnetic field applied to a domain is increased, it starts expanding. Now when the external magnetic field is removed, if the domain returns to its original position it is called reversible domains and if the domain doesn't returns to its original position it is known as irreversible domains.

15. Distinguish the properties of soft and hard magnetic materials.

S.No.	Soft	Hard
1.	They can be easily magnetised and demagnetised.	They cannot be easily magnetised (or) demagnetised.
2.	Loop area is less and hence the hysteresis loss is minimum.	The loop area is large and hence the hysteresis loss is maximum.
3.	Susceptibility and permeability is high	Susceptibility and permeability is low.
4.	Retentivity and Coercivity are small	Retentivity and Coercivity are large.
5.	They have low eddy current loss.	They have high eddy current loss.
6.	These materials are free from irregularities like strain or impurities.	These materials have large amount of impurities and lattice defects.

16. What are the requirements (required properties) of a transformer core material and electromagnets?

(I) A **transformer core** material should have the following requirements (properties)

(i) High resistivity

(ii) Low eddy current losses

(II) An **electromagnet** should have the following requirements (properties)

(i) High initial permeability

(ii) Low coercivity.

17. What is meant by eddy current and eddy current losses?

When an alternating magnetic field is applied to the material, it induces an e.m.f and sets up a large current in the material. This current is known as eddy current and the power loss is called eddy current losses.

18. What is meant by Garnet? Give examples.

Garnet is a ferrimagnetic material with a typical formula $Me_3Fe_5O_{12}$

where, $Me_3 \rightarrow$ Trivalent metal ion

$Fe_5 \rightarrow$ Trivalent ferric ion

Examples: Gadolinium Gallium Garnet, Yttrium Iron Garnet.

Properties

(i) They have high resistivity

(ii) They have low hysteresis loss

19. What is GMR?

If the charge in electrical resistance is very high compared to the magnetisation, it is called as Giant Magneto-Resistance (GMR) and this effect is called GMR effect.

20. What are ESD magnets? Give its properties.

ESD magnets are Elongated Single Domain magnets, which are made by very small particles with very high magnetisation. Hence these ESD magnets possess the following properties

Properties

(i) They are highly stable.

(ii) They have single domain structure.

(iii) They possess large magnetisation.

21. What is meant by Magnetic HDD? Give the principle of storing data in HDD.

Hard disk drives [HDD] made up of magnetic garnet materials are called ***magnetic hard disk drives***. It is a mass data storage device recently used for storing data to a very high level in terms of Tera bytes.

Now-a-days GMR [Giant Magneto Resistive] sensors, which has a very high magnetic sensitivity are used to read the data at greater speed.

Principle

In Hard disk drives, the binary data in terms of zero's (0) and one's (1) are stored by inducing magnetic moment in a thin magnetic layer and GMR effect is used as the principle to read the data in HDD.

Here ***zero(0) represents missing transition*** and ***one (1) represents transition in the medium.***

22. What are the advantages and disadvantages of HDD?

Advantages

1. HDD's can store data interms of Terabytes and in future it can store data interms of Petabytes and Exabytes.
2. It is has very large storage capacity.
3. It is compact in size and can be easily transferred from one place to another.
4. The size of the recording medium in HDD shall be reduced upto few nano-metres using nanotechnology.
5. GMR sensors are non diffusive and are very sensitive in reading.

Disadvantages

1. HDD is slower than SSD [solid state drives].
2. They consume more power and will damage, when dropped even at a smaller distance.
3. Sometimes the data in HDD may be corrupted, due to thermal radiation.
4. HDD has bulkier form factor.
5. The GMR noise ratio is high for the nano size recording media as it is temperature dependent.

23. Whatis the role of GMR sensor in Magnetic HDD

1. Giant magnetoresistive (GMR) effect is the principle used to read/retrieve the data from the recording medium.
2. When the GMR sensor is made to move near the recorded medium, then, the resistance of the GMR sensor varies, with respect to the orientation of the magnetic moments as follows.
3. ***When the layers are magnetised in parallel manner****, then the resistance in the GMR sensor is minimum and therefore maximum current flows through the sensor,* ***which represents the data as one (1)****, as shown in Fig. 3(f).*
4. ***When the layers are magnetised in antiparallel manner****, then the resistance in the GMR sensor will be maximum and therefore minimum (or) no current*

1. ***What is the principle of semiconductor laser?*** **(Jan. 2009)**

The electron in conduction band combines with a hole in the valence band and hence the recombination of electron and hole produces energy in the form of light. This photon, in turn may induce another electron in the conduction band to valence band and thereby stimulate the emission of another photon.

2. ***Mention any four advantages of LED in electronic display.*** **(Jan. 2006)**

(i) Very small in size.

(ii) Different colours of display.

(iii) Works under a wide range of temperature.

(iv) It has a very wide range of operation.

3. ***How is a light emitting diode different from a semiconductor laser?*** **(Dec. 2003)**

S.No.	LED	LASER
1.	It requires low current density.	It requires high current density.
2.	Junction of diode need not be polished.	Junctions of the diode should be highly polished.
3.	Minority carrier injection should take place	Stimulated emission will take place.
4.	Power output is low.	Power output is high.
5.	Intensity is less.	Intensity is very high.

ADDITIONAL PART A QUESTIONS & ANSWERS

1. What are optical materials? Give its types.

Materials which are very sensitive to light are called optical materials. In general there are 3 types of optical materials. *viz*

(i) Transparent materials: They transmit more light.

(ii) **Translucent materials:** They transmit light partially.

(iii) **Opaque materials:** They will not transmit any light.

2. What is an opto-electronic device?

The device in which the photons (light) interact with the electron is called an opto-electronic device.

The materials used in opto-electronic device are called optical materials.

3. Explain the term, "Delayed transmission".

When photons are made to incident on the optical material, it creates oscillatory dipoles. These oscillatory dipoles when return to ground state by emitting the same frequency as that of its excitation, without any loss in energy, it is termed as delayed transmission.

4. Differentiate normal dispersion and anomalous dispersion.

S.No.	Normal dispersion	Anomalous dispersion
1.	The range of frequencies where the refractive index increases with the increase in frequency is called normal dispersion.	The range of frequencies where the refractive index decreases with the increase in frequency is called anomalous dispersion.
2.	Transparent substances will have this effect.	Transparent substances will not have this effect.
3.	It is a real function.	It is a complex function

5. Explain the phenomenon of reflection, using polarised charges.

The reflecting phenomenon depends on the density of polarisation. When light is made to incident on a dense gas of free electrons, it polarises, the charges, and creates oscillatory dipoles. If these polarised charges re-radiate the energy without lossing their energy to the lattice points, it is called reflection.

6. Define skin depth and skin layer.

When light passes through metals it produces conduction current. The maximum distance upto which it can travel in the metal is called skin depth and last layer inside the metal, upto which the conduction current passes is called skin layer.

7. Distinguish between radiative and non radiative transition.

S.No.	Radiative transition	Non-radiative transition
1.	Here the electrons in conduction band combines with the holes in the valence and radiate the energy in the form of light.	Here the electrons in conduction band collides with the lattice points and radiate the energy in the form of heat.
2.	Photons are emitted.	Phonons are produced.

8. What is meant by absorption edge? Give example.

The wavelength that is absorbed with respect to the energy band gap of the material is called absorption edge.

Example: Suppose for a material has an energy band gap $E_g = 5641$ Å which corresponds to the wavelength of yellow colour, then the material will absorb the yellow colour and emits the light of greater wavelength (i.e.,) red colour.

9. What is the effect of optical absorption in semiconductors.

The optical absorption in semiconductors produces the following effects.

(i) It forms excitons.

(ii) It produces photo-conductivity.

(iii) It excites the crystal lattice vibrations.

(iv) It also excites the free electrons and holes.

10. Define trap, its origination and types.

Trap is an intermediate energy level presents in the energy band gap. These traps arises due to the presence of impurity atoms and imperfections in the crystal. There are two types of trape *viz.*, (i) Trapping centre and (ii) Recombination centre.

11. Define luminescence and give its types.

When an atom in an excited state returns to ground state by emitting light, it is called luminescence.

Based on the types of excitation, luminescence can be classified into many types *viz.*

(i) Photo-luminescence;

(ii) Electro-luminescence;

(iii) Cathodo-luminescence;

(iv) Thermo-luminescence;

(v) Injection-luminescence

12. Distinguish between fluorescence and phosphorescence.

S.No.	Fluorescence	Phosphorescence
1.	In fluorescence the time taken for the excitation of an atom will be equal to the time for which the luminescence persists	In phosphorescence the time taken for the excitation of an atom will be lesser than the time for which the luminescence persists.
2.	Here, luminescence persists for a short period	Here, luminescence persists for a longer time
3.	The materials which exhibits fluorescence are called fluorescent materials.	The materials which exhibits phosphorescence are called phosphors

13. Give any two differences between characteristic luminescence and non-characteristic luminescence.

S.No.	Characteristic luminescence	Non-characteristic luminescence
1.	Luminescence produced due to the impurity ions alone is called characteristic luminescence.	Luminescence produced due to both impurity ions and other ionic charges is called non-characteristic luminescence.
2.	Here activator alone participates in the excitation process	Here both activator and co-activator participates in the excitation process
3.	Quick process	Slow process

14. What are activators and co-activators?

Activators: The impurity ions which leads to the production of traps are called activators.

Co-activator: The ionic charges present along with the impurities are called co-activators.

15. Distinguish between electro-luminescence and cathodo-luminescence

S.No.	Electro-luminescence	Cathodo-luminescence
1.	When electric field is applied to an optical material the electrons move from valence band to conduction band. When this electron emits light during deexcitation it called electro-luminescence.	When a high energetic electron beam from a hot cathode is made to impinge over an optical material, it produces electron-hole pair. If these electron hole pair recombines to produce light, it is called cathodo-luminescence.
2.	Excitation is due to a.c/d.c field	Excitation is due to electron bombardment
3.	This principle is used in LED's	This principle is used in CRO.

16. What is meant by injection luminescence? Give example.

When the majority carriers are injected from p to n and n to p region, they become excess minority carriers. Then these excess minority carriers diffuses away from the junction and recombines with the majority carriers in p and n regions and emits light. This phenomenon is known as injection luminescence.

Example: Light emitting diode (LED)

17 Distinguish between active and passive display devices

S.No.	Active display device	Passive display device
1.	These devices display (or) emits the light radiation in their own, due to application of field.	These devices modulates the incident radiation and then reflects (or) transmit the light.
2.	***Example:*** Light Emitting Diode (LED)	***Example:*** Liquid Crystal Display (LCD)

18. What are the differences between trapping centre and recombination centre

S.No.	Trapping centre	Recombination centre
1.	It is a type of a trap which captures an electron (or) hole and then reexcite to free state.	It is a type of trap in which electrons and hole recombines with each other to produce phonons.
2.	Here the charge carries are temporarily trapped.	Here the charge carriers are permanently trapped.

19. What is meant by LED? Give its principle.

An LED is an abbreviation of Light Emitting Diode. It is a semiconductor $p-n$ junction diode which converts electrical energy to light energy under forward biasing.

Principle: *Injection luminescence.* i.e., When the majority carriers are injected from p to n and n to p region, they become excess minority carriers. Then these excess minority carriers diffuses away from the junction and recombines with the majority carriers in p and n regions and emits light.

20. Why group III and group V elements alone should be chosen for manufacturing LED's.

If the wavelength of the light emitted has to lie in the visible region (i.e.,) 4000 Å to 7200 Å, Energy band gap of the material chosen should have the range from 1.723 to 3.101 eV. [$\because$ $E_g = \frac{12400}{\lambda}$ eV]. Since the intermediate compounds of group III and group V has E_g between 1.72 to 3.1 these elements are chosen for manufacturing LEDs.

21. What are the properties of LED?

1. Cost is high.
2. Not suitable for large area display.
3. High consumption power (milliwatts).
4. Operating temperature is 0° to 70°C
5. Response time is in nano seconds (10^{-9} sec)
6. Intensity of light can be controlled.
7. Different colour displays are available at low cost.

22. *Give any two direct and indirect band gap LED materials.*

Direct band gap LED materials

(i) Gallium arsenide [IR radiation]

(ii) Gallium arsenide phosphide [Yellow/orange colour]

Indirect band gap LED materials

(i) Gallium phosphide doped with nitrogen [green colour]

(ii) Gallium phosphide doped with zinc [Red colour]

23. *Why is the shape of LED made hemispherical. (or) Why dome shape LED is preferred than a planer LED.*

In planer LED's the emitted light strikes the material interface at an angle greater than the critical angle and the reflection loss will be very high.

Therefore, to minimise the reflection loss, hemispherical dome shaped LED is made, in which the angle at which the emitted light strikes the interface can be made less than the critical angle.

24. *Mention any two optical sources?*

(i) Light emitting diode (LED) – In LED's we have two types, *viz.*, (1) Planar and (2) Dome shaped LED.

(ii) Laser diodes (LD) – In laser diodes we have many types, in which homojunction laster, heterojunctions laser, injection laser diode etc. are widely used as fiber optic sources.

25. *How an LED can be converted into laser diode?*

In a semiconductor diodes if the emission is not stimulated, the device is called light emitting diode (LED).

To convert LED into a laser diode, high current density is required to achieve population inversion and the opposite surfaces should be polished.

26. *What is the principle used in the emission of photo current in p–n junction photo diode?*

When a p-n junction diode is exposed to light (photons), under reverse bias, it produces electron and hole pairs. Due to the flow of these charge carriers, it produces a reverse current.

27. *Mention any four type of photo diodes.*

Based on the modes of operation, there are different types of photo-diodes *viz.*

1. PIN [*p* type - intrinsic - *n* type] photo diode.
2. APD [Avalanche pin photo-diode].
3. Schottky photo-diode.
4. Solar cell etc.

28. *What are the advantages and disadvantages of photo diode?*

Advantages

1. They have long life period.
2. It is light in weight.
3. It is very compact (small in size).
4. Noise of the photo diode is very less.
5. It can be rugged mechanically.
6. The response of the photo-diode is wide spectral.

Disadvantages

1. Here the dark current is temperature dependent.
2. The thermal stability is very poor.
3. Amplification is compulsorily required for better performance.
4. Efficiency is poor in rainy/winter seasons.

29. *Give any four applications of photo diode.*

Applications

1. Photo-diodes are used in charge-couple devices [CCD], photo-conductors and photo-multiplier tubes.
2. They have wide applications in clocks, radio, camera, street lights, etc.
3. They are used for lighting regulation and in optical communication systems.
4. Photo-diodes are used in electronic devices such as smoke detectors, CD players, TVs, remote controls etc.
5. In medicine they are used in computed tomography (CT) instrument.

30. *Write the principle of operation in a solar cell.*

A solar cell is a basically a large area photo-diode which converts sunlight [solar energy] directly into electricity [Electrical energy], with larger efficiency, of photon absorption.

31. *Mention any two merits and demerits of solar cell.*

Merits

1. The energy used by solar cell is a renewable energy source i.e., sun.
2. These cells are eco-friendly and save electricity charges.
3. It is a pollution free device with higher efficiency.
4. Life time and durability is longer.

Demerits

1. Investment/installation cost is high.
2. It is a seasonal energy, which can't work under winter/rainy seasons.
3. It occupies more space for solar panels to be installed.
4. The electrical energy generated should always be converted from DC to AC, which is practically difficult.

32. *List out any four applications of solar cell.*

1. Solar cells are used in the production of electricity to our daily needs.
2. Solar cells also provide electricity which may be used for commercial purposes.
3. They are used in artificial satellites and in space probes.
4. Solar panels are used in calculators, watches, street lights, toys etc.

33. *What is the working principe of OLED?*

An electron moves from the cathode to the emissive layer and the hole moves from the anode to the conductive layer and they recombine to produce photons, is the principle used emit light in OLED.

34. In what way OLED is advantage than LED/LCD

Advantages

OLED's have more advantages, when compared to CRT, LCD and LEDs. Some of them are as follows.

1. OLED is very thin, and more flexible.
2. They are light in weight.
3. Light emission is brighter than normal LED's.
4. The conductive and emissive layers can be increased to increase the efficiency of OLED.
5. OLED's do not require backlighting like LCD's.
6. They have large field of view [About 170°]

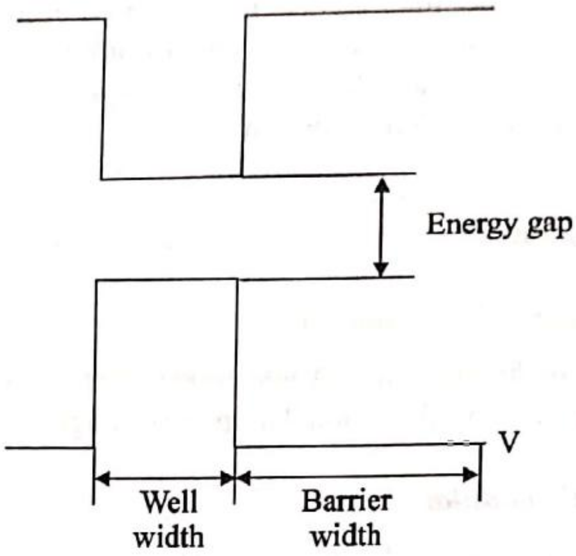
Disadvantages

1. Cost of manufacturing is very high.
2. OLED's can be easily damaged when water falls on it.
3. Blue OLED have less life time, when compared to Red OLED.
4. Maintenance cost also increases due to different life time.

35. List out the recent applications of OLED.

1. OLED's are widely used in cell phones, digital cameras etc.
2. They are also used in TV screens, computer

43. What is a quantum well? Draw a quantum well structure.



When two semiconductors of different band gap energies and of thickness comparable to the electron mean free path, alternate to form a synthetically modulated structure, then such structure is called quantum well structure.

44. What is electro absorption?

A change in optical absorption with applied electric field (or) voltage is called electro absorption.

45. Which factors determines the modulation bandwidth? What are carrier dynamic parameters?

A large excitonic absorption and a high change in the absorption per unit applied bias increases the modulation depth.

48. ***What is meant by photon assisted tunneling?***

When photon of energy $h\gamma < E_g$ is given to the potential barrier, the given energy is absorbed and the tunneling barrier thickness is reduced. So the overlap of the wave functions increases further. By this condition, the valence electrons easily tunnels to the conduction band. Therefore the franz-keldysh effect is called photo-assisted tunneling effect.

49. ***What is meant by beam switching (or) optical switching (or) photonic?***

Using high modulating systems, we can deflect or switch the direction of

PART A QUESTIONS & ANSWERS

1. ***What is the difference between the band gap of a material to the nanomaterial?***

In ordinary material, the band gap will be smaller. For nanomaterial, the band gap will be greater.

2. ***In quantum dot, how will be the nature of the material and band gap.***

In the case of quantum dots, the smaller the particle the bigger the band gap.

3. ***What is meant by Ballistic transport?***

When the mean free path of the electron is longer than the dimension of the medium through which the electron travels is called Ballistic transport.

For Ballistic transport condition $L << L_m$.

4. ***Define quantum conductance.***

The quantum conductance or conductance quantum 'G_0' is the quantized unit of electrical conductance.

It is defined as $G_0 = \frac{2e^2}{h} = 7.748 \times 10^{-5}$ mho

5. ***Define resistance quantum.***

The reciprocal of the conductance quantum is called resistance quantum (R_0).

$$R_0 = \frac{1}{G_0} = \frac{h}{2e^2} = 12.9\,\text{kohm}$$

6. ***Define quantum dot laser.***

A quantum dot laser is a semiconductor laser that uses quantumn dots as the active medium in its light emitting region.

7. ***What are the advantages and disadvantages of quantum dot laser***

Advantages:

(i) Broad spectrum with a specific wavelength of light emission can be obtained by changing dot size.

(ii) Because of very small active volume, only very less population inversion is necessary for lasing.

Disadvantages:

(i) It is very difficult to form high quality dots [Uniform size and Higher density]

(ii) Difficult to manufacture because of nanometer size.

8. ***What are the applications of quantum dot laser?***

Applications

(i) QD lasers are used in medicine [optical coherence tomography].

(ii) QD lasers are used in display technologies, Spectroscopy and telecommunications. QD lasers are used in optical transmission system and optical LANs.

9. ***What is meant by bulk material?***

The bulk material is a collection of atoms having property that are from individual atoms.

10. ***Define density of energy states?***

Density of energy is defined as the number of available energy states per unit volume, per unit energy in a solid.

11. ***Write the equation for an electron density in a conductor at T = 0K.***

The electron density in a conductor at T = 0K is

$$n_e = \frac{\pi}{3}\left(\frac{8m}{h^2}\right)^{3/2} E_F(0)^{3/2}$$

12. ***Whether fermi energy vary on material's size? If yes or no, justify your statement.***

No, since electron density is the property of the material, the Fermi energy does not vary with materials size. Fermi energy is the same for a particle of copper as it is for a brick of copper.

13. ***What will happen to the band gap when the volume is reduced from that of a solid to a nano material?***

The band gap gets bigger as the material gets smaller.

If the volume is reduced from that of a solid to that of a nano material the band gap will widen.

14. *What is meant by Tunnelling ?*

The phenomenon in which a particle, like an electron, encounters an energy barrier in an electronic structure and suddenly penetrates is known as tunnelling.

15. *What is meant by quantum confinement?.*

The effect achieved by reducing the volume of a solid so that the energy levels within it becomes discrete is called quantum confinement.

16. *What we will observe when we decrease the size of the particle to nano size?*

It we decrease the size of the particle to nano size, the decrease in confining size creates the energy levels discrete. The formation of discrete energy levels increases or widens up the band gap and finally the band gap energy also increases.

17. *What is meant by quantum confined structure?*

A quantum confined structure is one which the motion of the electron or holes are confined in one or more directions by potential barriers.

18. *Define the term quantum well, quantum wire and quantum dot.*

An electrically isolated region, like a thin film, where electrons are constrained in one dimension and exhibiting quantum behaviour is called quantum well.

An electrically isolated region, like a nano tube or nano scale wire, where electrons constrained in two dimensions and exhibiting quantum behaviour is called quantum wire.

An electrically isolated region, such as a particle or a portion of a bulk semi conductor, where electrons are constrained in all three dimensions, creating an artificial atom that exhibits quantum behaviour is called quantum dot.

19. *Write any two applications of quantum well, quantum wire and quantum dot.*

Quantum well

1. Quantum wells are now widely used to make semiconductor layers and other important devices.
2. Quantum well infrared photodetectors are also based on quantum wells, and are used for infrared imaging.

Quantum wire

1. Quantum wires can be used for transistors.
2. A quantum wire application is nano bar codes which is used in medical field. Nano bar codes are made different quantum wires of different metals that have different reflectivity.

Quantum dots

1. Quantom dot may be used as a basic building block in making a quantum computer.
2. The quantum dot applications in various fields include blue-laser diodes, single electron transistor, light-emitting devices, etc

20. ***How the density of states is proportional to the energy in one dimension, two dimension and three dimension.***

(i) In one dimension, density of states is proportional $E^{-1/2}$.

(ii) In two dimension, density of states is proportional to energy E.

(iii) In three dimension, density of states is proportional to $E^{1/2}$.

21. ***Define coulomb blockade.***

The resistance to electron transport caused by electrostatic coulomb forces in certain electronic structures, including quantum dots and single electron transistors is called coulomb blockade.

22. ***What is the purpose of coulomb blockade?***

Coulomb blockade helps to prevent constant tunnelling to and from a quantum dot.

23. ***How coulomb blockade prevent unwanted tunnelling?***

The coulomb blockade can prevent unwanted tunnelling, when energy is much higher than the thermal energy of an electron. The condition for the coulomb blockade is therefore $E_C >> K_B T$.

24. ***What is meant by single electron transistor?***

A transistor made from a quantum dot that controls the current from source to drain one electron at a time is called single electron transistor.

25. What are the main criteria for the single electron phenometer to occur?

For single electron phenomena to occur, we have to keep the single electron or quantum dot in isolation.

26. Explain the rules which used for the single electron phenomena to occur.

There are two rules:

Rule 1

The energy needed to add one electron to the dot, or charging energy, E_C, must be significantly higher than the thermal energy of an electron

$$\text{i.e.,}\quad E_C = \frac{e^2}{2C_{dot}} >> K_B T$$

Rule 2

The uncertainty of the charging energy must be less than the charging energy itself. This is accomplished if

$$R_t >> \frac{h}{e^2}$$

R_t = tunnelling resistance.

By following the above two rules, it becomes possible to manipulate electrons one at a time and single electron phenomena will occur.

In the single electron transistor, these two rules are used.

PART B QUESTIONS

1. Write a short note an band gap of nanomaterials
2. Derive the expression for density of states for different quantum confinements.
3. Explain quantum well, quantum wire and quantum dot.
4. Write a short note of a tunnelling.
5. Describe the construction and working of single electron transistor.
6. Explain the phenomena of single electron which is used in single electron transistor.
7. Describe the construction and working of quantum dot laser.
8. Explain the conductivity of metallic nano wire.
9. Derive an expression for quantum conductance and quantum resistance.
10. Describe the principle, construction and working of a quantum well laser.