UNIT I: CONDUCTING MATERIALS
PART – A

1) What is meant by a free electron?
Free electron is the electron which moves freely in all direction in the absence of external field. These electrons collide with each other and also with the lattice elastically and hence there is no loss in energy.

2) List out three main theories developed for metals
a) Classical free electron theory
b) Quantum free electron theory
c) Band theory of solids.

3) Give the postulates of free electron theory.
In a metal, the free electrons of an atom are free to move about the entire volume of the metal like the molecules of a perfect gas in a container. These free electrons in the metal are responsible for electrical conduction.

4) Define drift velocity.
The average velocity acquired by the free electron in a particular direction, due to the application of electric field is called drift velocity.

5) Define relaxation time. (DEC 12)
Relaxation time can be defined as the time taken by the free electron to reach its equilibrium position from its disturbed position in the presence of applied field.

6) Define mean free path. (JUNE 12)
The average distance traveled by an electron between two successive collisions is known as mean free path.

7) Define Mobility of Electrons.
The magnitude of the drift velocity per unit electric field is defined as the Mobility of electrons (μ).

$$\mu = \upsilon_d/E$$

8) Write the differences between drift velocity and thermal velocity of an electron.

S.No	Drift Velocity	Thermal velocity
1	The average velocity acquired by the free electron in the presence of electric field is called drift velocity.	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

9) Get the microscopic form of Ohm's law and state whether it is true for all temperatures.
According to classical free electron theory current density, J=σE: E=Jρ : Resistance=ρl/A: Voltage V= I ρl/A =IR. Microscopically we can write V=IR as E=Jρ. Since the resistivity varies with respect to the temperature, the microscopic form of Ohm's law is not true for all the temperatures.

10) Define Electrical conductivity.
The amount of electrical charges conducted (Q) per unit time (t) across unit area (A) of the solid per unit applied electrical field (E).

11) Define Wiedemann – Franz law.
It states that the ratio of the thermal conductivity (K) to the electrical conductivity (σ) of a metal is directly proportional to the absolute temperature (T) of the metal.

12) What are the similarities between electrical and thermal conductivity of metals?
a) The electrical and thermal conductivity decreases with the increase in temperature and impurities.
b) The electrical and thermal conductivity is very high at low temperature.

13) 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.

14) What are the sources of resistance in metals?
The resistance in metals is due to a) Impurities present in the metals b) Temperature of the metal c) Number of free electrons

15) What are the drawbacks of classical free electron theory?
a) It predicted the value of electronic specific heat as (3/2)R. But experimentally it is about 0.01R only
b) The ratio between thermal conductivity and electrical conductivity is not constant at low temperatures
c) The theoretical value of paramagnetic susceptibility is greater than experimental value
d) The electrical conductivity of semiconductors, ferromagnetism, photoelectric effect and blackbody radiation cannot be explained.

16) What are the merits of classical free electron theory?
a) It verifies Ohms law.
b) It explains the electrical conductivity and thermal conductivity of metals.
c) It is used to derive Widemann – Franz law.

17) Discuss the variation of resistivity of a conductor with respect to temperatures.
The variation of resistivity of a conductor with respect to temperatures can be explained as follows
a) The resistivity of a conductor remains almost constant at lower temperatures.
b) The resistivity is proportional to T^5 from low temperature to the Debye temperature.

18) Define Fermi energy level.
It is that state at which the probability of electron occupation is 50% at any temperature above 0 K and it is the level of maximum energy of the filled states at 0 K.

19) Define Fermi surface
Fermi surface (or) Fermi sphere is defined as the surface which is traced out by joining the loci of the end points of the wave vector k corresponding to the Fermi energy level.

20) What are the difference between quantum theory and zone theory?

S.No	Quantum theory	Zone theory
1	The electron is assumed to move in a region of constant potential	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	According to this theory the mass of the electron varies when it moves through periodic potential and is called effective mass of an electron.

21) Write the Fermi-dirac distribution function. (or) Define Fermi distribution function.
Fermi-dirac distribution function represents the probability of an electron occupying a given energy level.

$$F(E) = 1/(1+e^{(E-E_F)/KT})$$

22) Mention any two important features of quantum free electron theory of metals.

a) It shows that the energy levels of an electron are discrete.

b) The maximum energy level up to which the electron can be filled at 0K is denoted by Fermi energy level.

23) Define density of states. What is its use? (DEC 2012)

Density of states is defined as the number of energy states per unit volume in an energy interval. It is used to determine Fermi energy at any temperature.

24) What is work function?

The amount of kinetic energy required to move an electron from the outer orbit at absolute zero temperature is called work function.

25) What is Lorentz number?

The ratio between thermal conductivity (K) of a metal to the product of electrical conductivity (σ) of a metal and absolute temperature (T) of the metal is a constant. It is called Lorentz number and it is given by $L = K/\sigma T$

26) Calculate the drift velocity of the free electrons [with a mobility of 3.5×10^{-3} $m^2V^{-1}s^{-1}$] in copper for electric field strength of 0.5 V/m. (JUNE 2008)

$$\mu = \upsilon_d / E\ ;\ \upsilon_d = E/\mu;\ \upsilon_d = 3.5 \times 10^{-3} \times 0.5;\ \upsilon_d = 0.00175 \text{ m/s}$$

27) Use Fermi distribution function to obtain the value of F(E) for $E-E_F$ = 0.01 eV at 200 K.

$$F(E) = 1/(1+e^{(E-E_F)/KT});\ F(E) = 1/(1+e^{0.5797}) = 0.359$$

28) Calculate the electrical conductivity in copper if the mean free path of electrons is 4×10^{-8} m, electron density is 8.4×10^{28} m^{-3} and average thermal velocity of electron is 1.6×10^{6} m/s.

$\boldsymbol{\sigma = ne^2\lambda/m\upsilon}$ $= [(8.4\times10^{28})\times(1.6\times10^{-19})^2\times(4\times10^{-8})] / [(9.11\times10^{-31})\times (1.6\times10^{6})] = 5.9 \times 10^{7}$ mho m^{-1}

29) Find the relaxation time of conduction electrons in a metal of resistivity 1.54×10^{-8} ohm-m if the metal has 5.8×10^{28} conduction electrons / m^3.

$\boldsymbol{\tau = m/ne^2\rho}$ $= 9.11\times10^{-31} / [(5.8\times10^{28})\times(1.6\times10^{-19})^2\times(1.54\times10^{-8})] = 3.97\times10^{-14}$ s

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

$\boldsymbol{\upsilon_d = I/neA}$ $= 1 / [(8.5\times10^{28})\times(1.6\times10^{-19})\times(1.6\times10^{-6})] = 7.4\times10^{-5}$ m/s.

PART – B

1) State and prove Widemann – Franz law
2) Deduce a mathematical expression for electrical conductivity of a conducting material and hence obtain Widemann – Franz law.
3) (i) What are the postulates of free electron theory?
   (ii) Derive an expression for electrical conductivity.
   (iii) Get the microscopic form of Ohms law.
4) On the basis of free electron theory derive an expression for electrical conductivity. What are the sources of resistance in metals?
5) Give the mathematical expression for electrical conductivity and thermal conductivity of a conducting material. **(APRIL 2012)**
6) Describe the classical free electron theory and deduce Lorentz number. Also discuss the merits and demerits of classical free electron theory.
7) Write Fermi Dirac distribution function. Explain how Fermi function varies with temperature. **(JUNE 2011)**
8) Derive an expression for the density of states and based on that calculate the carrier concentration in metals. (**DEC 2012**)
9) With a neat diagram, derive an expression for density of states.
10) i) Based on classical free electron theory , arrive at the Widemann-Franz law.
   ii) Draw a graph showing the variation of Fermi level with change in temperature for the conducting material and explain it. **(JUNE 2011)**

UNIT II: SEMICONDUCTING MATERIALS
PART – A

1. State the properties of semiconductor.

At 0 K they behave as insulators. They have negative temperature coefficient of resistance. The resistivity lies between 10^{-4} to 0.5 ohm-meter.

2. Differentiate indirect band gap and direct band gap.

Indirect band gap	Direct band gap
They are made of single element. e.g. Ge, Si	They are made of single element. e.g. GaAs, Gap
Heat is produced due to recombination	Photons are emitted during recombination
current amplification is more	current amplification is less

3. What are applications of Hall Effect? (May 2011)

It is used to determine whether the material is p type or n type.

It is used to find the mobility of charge carriers. It is used to design the magnetic flux meters.

4. Mention the advantages of semiconducting materials.

It can behave as insulators at 0 K and as conductors at high temperatures.

It is used in manufacturing of diodes, transistors, LED, IC etc.

5. What is meant by doping and doping level?

The process of adding impurities like Ga, In, etc to pure intrinsic semiconductor is called doping. The maximum extent up to which the impurity can be added is called doping level.

6. Compare n type and P type. (June 2008 & June 2010)

n type semiconductors	p type semiconductors
It is obtained by doping an intrinsic semiconductor with pentavalent impurity.	It is obtained by doping an intrinsic semiconductor with trivalent impurity
It has donor energy level is very close to conduction band	It has acceptor energy levels very close to valence band.

7. Define Hall Effect?

When a current carrying conductor is placed in a transverse magnetic field, an electric field is produced inside the conductor in a direction normal to both the current and magnetic field. This effect is known as Hall Effect.

8. What are elemental semiconductors? Give some examples.

Elemental semiconductors are made from single element of the fourth group elements of the periodic table. It is also called as indirect band gap semiconductors. Ge, Si.

9. What are compound semiconductors? Give some examples. (June 2008)

Compound semiconductors are made from third and fifth group elements or second and sixth group elements of the periodic table. It is also called as direct band gap semiconductors.

10. What is Fermi level in a semiconductor?

It is the energy level situated in the bandgap of the semiconductor, exactly located at the middle of the bandgap in a intrinsic semiconductor.

11. Write the expression for the electrical conductivity of an intrinsic semiconductor.

Electrical conductivity $\sigma = n_i(\mu_e + \mu_h)$

Where n_i – intrinsic carrier concentration

μ_e – mobility of electrons

μ_h – mobility of holes

12. What is meant by doping and doping agent?

Adding impurities to a pure semiconductor is known as doping and the added impurity is called doping agent.

13. What are the differences between the intrinsic and extrinsic semiconductors?

S.No.	Intrinsic semiconductor	Extrinsic semiconductor
1.	It is a pure form of the semiconductor	Semiconductors which are doped with impurities.
2.	Charge carriers are produced only by thermal agitation.	Charge carriers are produced by impurities
3.	They have low electrical conductivity	They have high electrical conductivity
4.	They have low operating temperature.	They have high operating temperature.

14. Explain the concept of hole? (May 2012)

When a covalent is broken an electron escapes to the conduction band leaving behind an empty space in the valence band. This missing of an electron is called a hole.

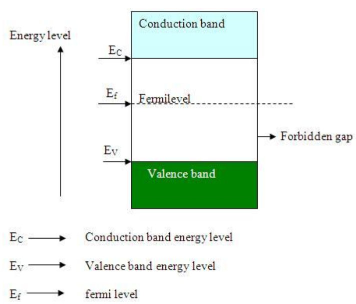
15. What is meant by donar energy level?

When a pentavalent impurity is doped with the extrinsic semiconductor, an electron produces an energy level called donar energy level.

16. What is meant by acceptor energy level?

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

17. Sketch the Fermi energy level of an intrinsic semiconductor (JUNE 2011)



18. A sample of n-type semiconductor with a current of current density 50A/m^2, flowing across, it is subjected to a transverse magnetic field of 0.2T. If the Hall field developed is 3 X 10^{-4} V/m, calculate the concentration of conduction electron. **(JUNE 2011)**

$$n_e = J_{x.B} / E_{H..}e = 50 \text{ X } 0.2/3\text{X}10^{-4} \text{ X}1.602\text{X}10^{-19} = 2.0807 \text{ x}10^{-23}/\text{m}^3.$$

19. What are compound semiconductors? How do they differ from elemental semiconductors? (JUNE 2011, DEC 2012)

Compound semiconductors are made from third and fifth group elements or second and sixth group elements of the periodic table. It is also called as direct bandgap semiconductors. Elemental semiconductors are made from single element of the fourth group elements of the periodic table. It is also called as indirect bandgap semiconductors. Ge, Si.

20. Write an expression for electrical conductivity of an intrinsic semiconductor. (Dec 2012)

$$\sigma_i = 2e\left(\frac{2\pi kT}{h^2}\right)^{3/2}(m_e^* m_h^*)^{3/4} e^{\left(-E_g/2kT\right)}(\mu_e + \mu_h)$$

21. Define Hall coefficient and write the expression for it? (June 2009)

Hall field per unit current density per unit magnetic induction is called Hall Coefficient.

$R_H = E_H/J_xB$

22. How are n-type & p-type semiconductors are produced? (May 2009)

When a small amount of pentavalent impurity is doped to a pure semiconductor it becomes n-type semiconductor.

When a small amount of trivalent impurity is doped to a pure semiconductor it becomes p-type semiconductor.

23. If the effective mass of the electron is equal to twice the mass effective mass of the hole, determine the position of the Fermi level in an intrinsic semiconductor from the centre of forbidden gap at room temperature.

$$E_F = \frac{E_g}{2} + \frac{3}{4} kT \ln\left(\frac{m_h^*}{m_e^*}\right)$$

$$E_F = \frac{E_g}{2} - 0.0135\, eV$$

The Fermi level is below the centre of the forbidden gap by 0.014 eV

24. Find the resistance of an intrinsic Ge rod of 1 cm long 1 mm wide and 1 mm thick at 300 K. the intrinsic carrier density is 2.5 x $10^{19}/m^3$ at 300 K and the mobilities of electron and hole are 0.39 and 0.19 $m^2\,V^{-1}\,s^{-1}$ (0CT – 2009)

$\sigma = n_i(\mu_e + \mu_h)$ = 2.32 $\Omega^{-1}m^{-1}$

Resistance=ρl/A = 4310 ohms.

25. A semiconductor crystal 12 mm long, 5 mm wide, and 1 mm thick has a magnetic flux density of 0.5 wb/m^2 applied from front to back perpendicular to longest faces. When a current of 20mA flows lengthwise through the specimen, the voltage measured across the width is found to be 37μV. What is Hall coefficient of the semiconductor? (Dec 2009)

$R_H = V_H b / I_H B = 3.7\times10^{-6}\ C^{-1}m^3$

26. The intrinsic carrier density at room temperature in Ge is 2.37 x $10^{-19}/m^3$. If the electron and hole mobilities are 0.38 and 0.18 $m^2\,V^{-1}\,s^{-1}$ respectively. Calculate its resistivity. (Dec 2010)

Conductivity $\sigma = n_i(\mu_e + \mu_h)$ = 2.1235 $\Omega^{-1}m^{-1}$

Resistivity ρ = 1/ σ = 0.4709 Ωm

27. Given an extrinsic semiconductor, how will you find whether it is n-type of p-type? (June -2010 & 2012)

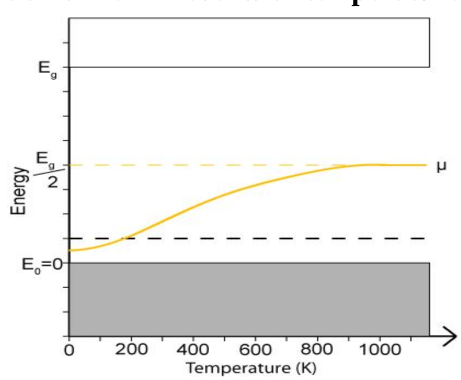
The n-type and p-type semiconductors can be distinguished by determining the Hall Coefficient using Hall Effect.

If the Hall coefficient is negative, then we can say that the material is n-type. And if the Hall coefficient is positive, then we can say that the material is p-type.

28. Compared with Ge, Si is widely used to manufacture the semiconducting devices. Why? (June 2013)

Si is available in abundance compared to Ge

29. Draw the graph for variation of Fermi level with temperature in p-type semiconductor. (Jun-13)



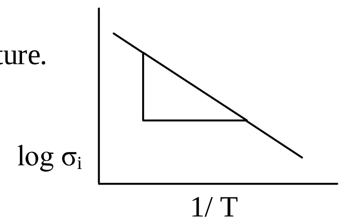
30. Write the expression for the electrical conductivity of an intrinsic semiconductor in terms of Forbidden energy gap. How one can measure energy gap experimentally?

Electrical conductivity $\boldsymbol{\sigma_i = A \exp(-E_g / 2kt)}$, Where A is a constant.

Taking logarithm on both sides $\boldsymbol{\log \sigma_i = \log A - E_g/2kt}$

Graph is drawn between the conductivity and temperature.

Slope of the straight line obtained gives $E_g / 2kt$.



Hence $\boldsymbol{E_g = 2k \times slope}$ Where k is called Boltzmann constant.

31. Discuss the variation of Fermi level with temperature in the case of P- type & N- type semiconductor.

P- type semiconductor: Fermi level shifts up and reaches the middle of the band gap by increasing temperature.

N- type semiconductor: Fermi level shifts down and reaches the middle of the band gap by increasing temperature up to 500K.

32. The mobilities of electrons and holes in a sample of intrinsic Ge at 300 K are 0.36 and 0.17 $m^2 V^{-1} s^{-1}$ respectively. Find the carrier concentration, if the resistivity of the specimen is 2.12 Ωm

$$\sigma = n_i e(\mu_e + \mu_h), \ \sigma = 1/\rho$$

$$n_i = \frac{\sigma}{e(\mu_e + \mu_h)} = 5.5 \times 10^{18}/m^3$$

33. For intrinsic Ge at 300K, n_i= 2.4 x $10^{19}/m^3$, μ_e and μ_h are 0.39 and 0.19 $m^2V^{-1}s^{-1}$respectively. Calculate the conductivity.

$$\sigma = n_i e(\mu_e + \mu_h)$$

$$= 2.4\times10^{19}\times1.609\times10^{-19}(0.39\times0.19) = 2.2 ohm^{-1}m^{-1}$$

PART – B

1. Derive an expression for density of electrons in conduction band of an intrinsic semiconductor.
2. Derive an expression for density of holes in valence band of an intrinsic semiconductor.
3. Discuss the variation of Fermi level with temperature in an intrinsic semiconductor.
4. Describe a method of determining the band gap of a semiconductor. How does electrical conductivity vary with temperature for an intrinsic semiconductor?
5. Derive an expression for a density of electrons in conduction band of a n-type semiconductor.
6. Derive an expression for a density of holes in p-type semiconductor.
7. Discuss the variation of carrier concentration with temperature in n-type semiconductor.
8. What is Hall Effect? Describe an experiment for Hall coefficient. **(JUNE 2011)**
9. (i) What are elemental and compound semiconductors? Give two examples. Compare their characteristics. **(JUNE 2011)**
   (ii) Describe the Hall Effect experiment to determine the Hall Coefficient and Hall Mobility
10. Silicon contains 5 x10^{28} atoms/m^3. In an n-type Si sample the donor concentration is 1 atom per 2.5 x 10^7 Si atoms. Find out the position of Fermi level at 300 K. Assume that effective mass of an electron is equal to the free electron mass.
11. A sample of silicon doped with 10^{23} phosphorous atoms/m^3. Find the Hall Voltage in a sample with a thickness 100 μm, current 1 mA and magnetic field as 0.1 Wb/m^2 (Assume μ_e = 0.07 μm /vs) **(JUNE 2009)**
12. The density of silver is 10.5 x10^3 kg/m^3, the atomic weight of silver is 107.9 assume that the each Silver atom provides one conduction electron. The electron conductivity of silver at 20ºC is 6.8x10^7/ Ω^{-1}m. Determine the carrier concentration and mobility of electrons if N = 6.02x10^{26} atom/Kg mol **(Jun – 2010)**
13. The Hall coefficient of the specimen of doped silicon is found to be 3.66x10^{-4} m^{-3}/C. The resistivity of the specimen is 8.93x10^{-3} Ωm. Find the mobility and density of the charge carriers. **(Dec 2010)**
14. The donor density of an n-type Ge sample is 10^{21}/m^3. The sample is arranged in Hall Experiment having magnetic field of 0.5T and the current density is 500 A/m^2. Find the Hall Voltage if the sample is 3mm wide **(May – 2007)**

UNIT – III-MAGNETIC AND SUPERCONDUCTING MATERIALS
PART - A

1. On the basis of spin how the materials are classified as Para, Ferro, Antiferro and Ferri magnetic. (Or) How will you differentiate magnetic materials based on their spin alignment? (Oct- 09)

i) Paramagnetic materials have few unpaired electron spins of equal magnitudes.
ii) Ferromagnetic materials have many unpaired electron spins with equal magnitudes.
iii) Antiferro 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.

Curie –weiss law is given by

$$\chi_m = C / T - \theta$$

Where C – Curie constant
T – Absolute temperature
θ – 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 ferromagntic material becomes paramagnetic material.

3. What do you mean by the term “magnetic domains” and “domain walls’?

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. What are the differences between hard and soft magnetic materials? (May – 2009)

S.No	Soft	Hard
1	They can be easily magnetized and demagnetized.	They cannot be easily magnetized or demagnetized.
2	Movement of domain wall is easy and hence even for a small applied field large magentisation occurs.	Movement of domain wall is not easy due to the presence of impurities and hence large applied field is required for magnetisation.
3	Loop area is less and hence the hysteresis loss is minimum.	The loop area is large and hence the hysteresis loss is maximum.
4	Examples: Iron, silicon alloys, ferrites, Garnets etc.	Carbon steel, tungsten steel, Chromium steel

5. Define the terms remenance/retentivity and coercivity.

Remenance is the property of the magnetic material by which it retains some magnetisation when the magnetising field is reduced to zero.It is expressed in terms of weber / m2.

Coercivity is the property of the magnetic material by which it requires a demagnetising force to destroy the residual magnetism in it. It is expressed in terms of ampere turn /m.

6. Name two uses of soft magnetic materials.

i) Since soft magnetic materials can be easily magnetised or demagnetised, these are used to make electromagnets used in cranes.

ii) Due to their low hysteresis loss, they are also used as transformer core materials.

7. What are the requirements of a transformer core material?

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

8. Give the origin of magnetic moment in magnetic materials.

The magnetic moment originates from the orbital motion and spinning motion of electrons in atoms.

Particulalry ferromagnetism is mainly due to spin-spin interaction of unpaired electrons in the ferromagnetic atoms.

9. What are Ferrites?

Ferrites are the modified structure of iron with no carbon in which the magnetic moments are of unequal magntidues. They are made by two or more different kinds of atoms.

10. Define magnetic flux density and magnetic dipole with its unit.

It is defined as the number of magnetic lines of forces passing normally through unit area of cross section. Two opposite magnetic poles separated by some distance is called magnetic dipole.

11. Define magnetic field intensity and intensity of magnetization.

It is defined as the force experienced by a unit north pole placed at the given point in a magnetic field. It is defined as the magnetic moment per unit volume.

12. Define magnetic susceptibility and magnetic permeability.

It is defined as the ratio between intensity of magnetisation and the magnetic field intensity.

It is defined as the ratio between the magnetic flux density and the magnetic field intensity.

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

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

$$B = \mu_o(H+ I); \quad \mu = B / H \rightarrow B = \mu H$$

equating both we get

$$\mu H = \mu_o(H+ I)$$

$$\mu_o \mu_r H = \mu_o H (1+ I /H); \quad \mu_r = (1+ I /H);$$

$$\mu_r = 1 + \chi_m$$

14. Why diamagnetic materials are called weak magnets and ferromagnetic materials are called strong 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 magnetized. Thus diamagnetic materials are called weak magnets.

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

15. What is meant by Garnet? Give examples.

Garnets are the soft magnetic material which have high resistivity, low hysteresis loss and low current losses. These are used at microwave frequencies as non reciprocal microwave devices.

16. Define Bohr magneton.

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

1 Bohr magneton = 9.2×10^{-24} Am^2.

17. Explain the phenomenon of superconductivity.

The phenomenon of losing the resistivity absolutely to zero, when cooled to sufficiently low temperature.

18. What is transition temperature?

The temperature at which a normal material changes into a superconductor is called transition temperature.

19. What are the properties of superconductors?

- They have zero resistivity
- They exhibit perfect diamagnetism
- The entropy and specific heat decreases at transition temperature.
- The transition temperature varies due to the presence of isotopes.

20. What is Meissner effect?

When a material is cooled below its transition temperature the material becomes a perfect diamagnet. The magnetic flux originally present in the material gets ejected out of a superconductor.

21. What are high temperature superconductors? Give one example.

Any superconductor, if transition temperature is above 10 K is called High temperature superconductor.

Ex: - $Y Ba_2 Cu_3 O_{7-x}$ (YBCO) (T_c = 92K),

$HgBa_2 Ca_2 Cu_2O_8$ (HBCCO) (Tc= 153K)

22. Distinguish between Type – I and Type – II superconductors.

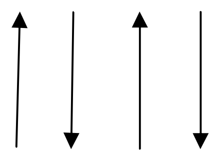
S.No	Type – I	Type – II
1	The material loses magnetisation suddenly	The material loses magnetisation gradually
2	There is only one critical magnetic field	There are two critical magnetic fields, lower and upper.
3	No mixed state exists.	Mixed state is present.

23. What is SQUID?

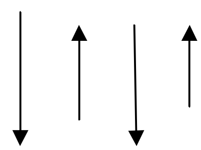
SQUID is the acronym for Superconducting Quantum Interference device. It is double junction quantum interferometer. Squids are based on the flux quantization in a superconducting ring.

24. Sketch the ordering of atomic magnetic moments in antiferromagnetic materials and ferrites. (JUNE 2011)

Antiferro magnetic material



Ferites



25. What are cooper pairs? (JUNE 2011)

The pair of electrons formed due to the electron – lattice – electron interaction with equal and opposite momentum and spins.

26. Mention the energies involved in domains of ferromagnetic material. (June – 2009)

1. Magneto static Energy 2. Crystalline Energy
3. Domain Wall Energy 4. Magnetostriction Energy.

27. What do you understand by the terms critical temperature and critical field of a superconductor? (June – 2009)

The magnetic field required to destroy the super conducting property is called critical magnetic field.

$H_C(T)=H_0((1-(T/T_C)^2)$

The temperature at which the normal conductors loses its resistivity and becomes a superconductor is known as transition temperature or critical temperature.

28. Define Energy product of a magnetic material.

The product of retentivity and coercivity is called the energy product. It represents the maximum amount of energy stored in the specimen.

29. What is domain theory of ferromagnetism? (Oct - 2009)

The domain theory of ferromagnetism is the explanation of the structure and Hysteresis property of ferromagnetic materials based on the concept of domains proposed by Weiss. Ferromagnetic material consists of a number of regions called domains which are spontaneously magnetized due to parallel alignment of all magnetic dipoles. The direction spontaneous magnetization varies from domain to domain.

30. What is meant by hysteresis loop? (Oct – 2009)

Hysteresis is the loss of energy taking in a ferromagnetic material through a complete cycle of magnetization. This loss is represented by the area enclosed by the hysteresis loop.

31. **What is anti-ferromagnetism?Give examples of antiferro magnetism materials? (June – 2010)**

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

Ex:- MnO, MnS

32. What are ferri magnetic materials and mention its properties? (June-2013)

Ferrites which exhibit ferrimagnetism are called ferrimagnetic materials. Susceptibility is positive and very large, there are equal numbers of opposite spins with different magnitudes such that the orientation of neighbouring spins is in anti-parallel manner.

33. Why are ferrites advantageous for use as transformer cores? (Dec-2010)

Ferrites are advantageous for use as transformer cores. Reason:

(i) Low H_C

(ii)Low eddy current loss

34. The magnetic field strength of copper is 10^6 ampere/metre if the magnetic susceptibility of copper is -0.8 X 10^{-5}, calculate the magnetic flux density and magentisation in copper?

$\chi = I/H$, $I = \chi H = -.8$ ampere/metre

$\mu_r = 1 + \chi = 0.999$

$B = \mu H = \mu_0 \mu_r H = 1.26$ weber/metre^2

35. A magnetic field of 1800 ampere/metre produces a magnetic flux of 3X10^{-5} weber in an iron bar of cross sectional area 0.2 cm^2. Calculate the permeability?

$B = \phi/A = 1.5$ Weber/m^2

$\mu = B/H = 8.33$ X10^{-4} Henry/metre

36. A superconducting tin has a critical temperature of 3.7K at zero magnetic field and a critical field of 0.0306T at 0K. Find the critical field at 2K.

$H_c = H_0(1-(T^2/T_C^2) = 0.02166T$

37. Calculate the critical current which can flow through a long thin superconduting wire of aluminium of diameter 10-3m. The critical magnetic field for aluminium is 7.9X103 ampere/metre.

$I_c = 2\Pi r H_c = 24.81$ ampere

38. Prove that the superconducting materials are diamagnets.

$B = \mu_0 (I+H)$

When B = 0, we get $0 = \mu_0 (I+H)$

Since $\mu_0 \neq 0$, we can write $I + H = 0$; or $I = -H$ or $I/H = -1 = \chi$.

39. The critical temperature for a metal with isotopic mass 199.5 is 4.185 K. Calculate the isotopic mass if the critical temperature falls to 4.133 k.(Assume α = 0.5)

$T_c = 1 / M^\alpha$ = 4.185/ 4.133 = $(M_2)^{0.5} / (199.5)^{0.5}$ = 204.536

40.The saturation magnetic induction of nickel is 0.65 Wb/m^2. If the density of Nickel is 8906 kg / m^3 and atomic weight is 58.7. Calculate the magnetic moment of the nickel atom in Bohr magneton.

$\mu_m = B_s / N\mu_0$ = $N = \rho A$ / atomic weight = 9.14 x 10^{28} atoms per m^3

μ_m = 5.66 x 10^{-24} A m^2 =0 .61 μB

PART – B

1. Discuss the domain structure in ferromagnetic materials. Show how the Hysteresis curve is explained on the basis of domain theory.
2. Describe the structure of ferrites. How the magnetic moment of ferrite molecule is calculated?
3. Briefly explain different types of magnetic materials and their properties.
4. Explain briefly the structure and applications of ferrites?
5. i) What are ferromagnetic materials?
   ii) Draw B-H curve for a ferro magnetic material and identify retentivity and coercive fields on the curve.
6. (i) Distinguish between Ferro, antiferro and ferrimagnetic materials **(Nov2003)**
   (ii) Classify the magnetic materials as Hard and Soft on the basis of Hysteresis loop.
7. (i) What is meant by Hysteresis Loss.
   (ii) Describe the formation of Hysteresis Loop using Domain Wall movement.
8. Briefly explain different types of energies involved in Domain Growth.
9. i) What are high temperature superconductors?
   ii) Explain Meissner effect?
   iii) Explain Type – I and Type – II superconductors.
10. Explain magnetic levitation and other applications of superconductors.
11. Explain the Various properties of superconducting materials.
12. Write short notes on (i) Cryotron, (ii) Josephson device (iii) SQUID (iv) Maglev
13. What is meant by superconductors? Describe the occurrence of superconductivity using BCS theory.
14. (i)What is meant by High temperature superconductors? Give Examples.
    (ii) Describe the crystal structure of $YBa_2Cu_3O_7$
    (iii) Explain the importance of oxygen content in $YBa_2Cu_3O_7$Superconductor
15. A Magnetic field strength of $2x10^5$ amp/m is applied to a paramagnetic material with relative permeability of 1.01. Calculate the values of B and M
16. A magnetic material of flux density and magnetization are 0.0044Wb/m^2 and 3300 A/m respectively. Calculate the magnetizing force and relative permeability of the material.
17. The Critical temperature of Hg with isotopic mass 199.5 is 4.185 K. Calculate the critical temperature when its mass (isotopic) Changes to 203.4
18. The saturation magnetic induction of nickel is 0.65 Wb/m^2. If the density of Nickel is 8906 kg / m^3 and atomic weight is 58.7. Calculate the magnetic moment of the nickel atom in Bohr magneton.

UNIT IV - DIELECTRIC MATERIALS

PART-A

1. What are the dielectrics?

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

2. What is meant by local field in a dielectric?

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 ranges of coulomb forces which are created due to the dipoles are called internal field (or) local field in dielectric.

$$E_{\text{int}} = E + \frac{P}{3\varepsilon_0}$$

3. Define dielectric loss and loss tangent? Why it occurs? (Nov 2002, June 2005)

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 is the loss in the energy in the form of heat is called as dielectric loss.

The power loss $P_L \alpha \tan \delta$, 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.

4. What is dielectric strength?

It is the minimum strength required per unit thickness of the dielectric material to produce dielectric breakdown.

5. Explain electrochemical breakdown in dielectric.

This type of breakdown occurs due to the presence of coirs and their mobility. These impurities cause 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.

6. Mention various dielectric breakdown mechanisms.

a) Intrinsic breakdown
b) Thermal breakdown
c) Discharge breakdown
d) Electrochemical breakdown
e) Defect breakdown

7. What is the effect of temperature on polarization?

- The electronic and ionic polarizations are independent of temperature.
- The orientation polarization decreases with the increase in temperature whereas the space charge polarization increases with the increase in temperature.

8. Give any two applications of dielectrics in transformer.

- Synthetic oils are used as coolant and in high voltage transformers.
- Mineral oils are used as transformer oils.

9. Write any two applications of dielectrics in capacitors.

- Ceramic materials are used in high frequency capacitors and disc capacitors.
- Mica is used in discrete capacitors.

10. Define ionic polarization.

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 polarization. Induced dipole moment

$\mu = \alpha_i E$ where α_i ionic polarizability

11. What is the effect of frequency of an a.c field on polarization?

In general the polarization decreases with increase in frequency. At optical frequencies electronic polarization is present and at infrared frequencies the ionic polarization occurs. The orientation polarization and space charge polarization will be absent at optical frequencies and will occur only at radio and audio frequencies respectively.

12. What are the ways in which the dielectric breakdown can be minimized?

(i) It should posses high dielectric strength and low dielectric loss.
(ii) It should have less density and thermal expansion.
(iii) It should be pure.
(iv) It should have high resistivity and sufficient mechanical Strength.

13. What is meant by ferro – electricity?

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

14. List out the applications of ferro – electrics.

(i) Electrets are also used to bond the fractured bones in the human body.
(ii) They are used as frequency stabilizers and crystal controlled oscillators.
(iii) Ferro – electric materials are used to produce ultrasonic waves.
(iv) Ferro – electrics are also used in SONAR, Strain gauges, etc.

15. What are the polar and non polar dielectrics?

The molecules having permanent dipoles are called as polar dielectrics and those do not have permanent dipole moment are called as non – polar dielectrics.

16. Define electric polarization.

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 is known as electronic polarization.The induced dipole moment $\mu = \alpha_e E$ where α_e electronic polarization

17. Define dielectric constant.

Dielectric constant is the measure of the polarization produced in the material. It is the ratio between the absolute permittivity and the permittivity of free space.

18. What is meant by dielectric breakdown? **(JUNE 2011)**

When external field applied to a dielectric material is greater than the critical field, the dielectric loses its insulating property and becomes conducting. Therefore a large current flows through the material.

19. What is meant by Piezo – electricity?

When a dielectric material acquires electric polarization due to the external mechanical pressure, it is called Piezo – electricity and these materials are called as Piezo – electrics.

20. What is meant by pyro – electricity?

When a dielectric material acquires electric polarization due to thermal energy applied externally, it is called as pyro – electricity and these materials are called as pyro electrics.

21. A layer of porcelain is 80 mm long, 20mm wide and 0.7μm thick. Calculate its capacitance with ε_r = 6.

Solution:

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}, \; C = \frac{8.854\times10^{-12}\times6\times80\times20\times10^{-6}}{0.7\times10^{-6}} = 1.21\times10^{-7}F$$

22. Prove $\chi_e = \varepsilon_r - 1$

We know the polarization $\vec{P} = \varepsilon_0 \chi_e E^{-1}$, $\chi_e = \dfrac{\vec{P}}{\varepsilon_o \vec{E}}$ ………... (1)

$$\frac{\vec{P}}{\vec{E}} = \varepsilon_0(\varepsilon_r - 1), \; \frac{\vec{P}}{\vec{E}\varepsilon_0} = (\varepsilon_r - 1) \quad \text{……….(2)}$$

Comparing equation 1 and 2 we get

$$\chi_e = \varepsilon_r - 1 \text{ Thus proved}$$

23. What is discharge breakdown?

When a dielectric placed in an external electric field, occurred gas bubbles present in the materials will easily ionize and produces large ionization current. This phenomenon is called as discharge breakdown.

24. What is defect breakdown?

These breakdowns occur due to the defects such as pores, cracks etc., in the dielectrics. These vacant positions which consist of impurities produces breakdown hence called defect breakdown.

25. What are the properties of ferroelectrics?

i. The dielectric constant of these materials do not vary with respect to temperature
ii. The dielectric constant 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 – electric materials exhibits hysteresis similar to that of a ferro magnetic materials

26. Determine the dipole moment and displacement of the centeroids of positive and negative charges for a neon atom in an electric field of 5 x 10 $^{-4}$ V / m. the atomic polarisability of neon is 4.3.x 10-^{41} Fm^2. (JUNE 2011)

$\mu = \alpha E = 4.3 \times 10^{-41} \times 5 \times 10^{-4} = 2.15 \times 10^{-44}$ C-m.

$D = \epsilon_0 E = 8.854 \times 10^{-12} \times 5 \times 10^{-4} = 4.427 \times 10^{-15}$ m.

27. Define polarization.

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

28. Name the four polarization mechanisms (May 2012)

Electronic, Ionic, Orientation and Space-charge polarization.

29. Define space-charge polarization.

When a dielectric is placed in an electric field 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 polarization.

30. Define orientation polarization

The orientation of polar molecules with respect to the field direction is called orientation polarization.

31. What is intrinsic breakdown.

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

32. Define thermal breakdown.

When a dielectric placed in an external electric field , the temperature inside the dielectric increases and heat may produce breakdown, this type of breakdown is known as thermal breakdown.

33. Define chemical and electro-chemical breakdown.

The mobility of ions increased due to increase in temperature, insulation resistance decreases and hence dielectric becomes conducting. This type of breakdown is called chemical and electro-chemical breakdown.

34. Calculate the dielectric constant of material which when inserted in parallel condenser of area 10 mm X 10 mm and distance of separation of 2 mm gives a capacitance of 10^{-9} F.

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}, \ \varepsilon_r = \frac{C\,d}{\varepsilon_0 A} = 2259$$

35. A parallel plate capacitor consists of two plates each of area 5X10^{-4} m^2. They are separated by a distance 1.5 mm and filled with dielectric of relative permittivity 6. Calculate the charge on the capacitor if it is connected to 100 V dc supply.

$$Q = CV$$

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}, \; Q = \frac{\varepsilon_r \varepsilon_0 A}{d} V = 1.77 \text{ X} 10^{-9} \text{ C}$$

PART – B

1. Discuss in detail the different types of polarization mechanisms in dielectrics and sketch their dependence on the frequency of applied electric field.
2. Explain the phenomenon of polarization in dielectrics? Arrive at the relation between the dielectric constant and atomic polarizability.
3. (i) What is meant by polarization in dielectrics?
   (ii) What are the different types of polarization? Briefly discuss.
   (iii) What is internal field in solid dielectrics?
   (iv) Obtain Clausius – Mosottoi equation and show how it is used to determine the dipole moment of a polar molecule.
4. Explain in detail about dielectric loss and various dielectric breakdown mechanisms.
5. Derive an expression for internal field and deduce the Clausius – Mosottoi equation.
6. Explain the different types of polarization mechanisms and thereby deduce the Langvein – Debye equation. **(JUNE 2011)**
7. What is dielectric breakdown? Write in detail about the various factors contributing to breakdown in dielectrics.
8. Classify the insulating materials and explain their properties and their practical applications in detail.
9. Write short notes on
   1) Various polarization mechanisms in dielectrics
   2) Dielectric loss and breakdown mechanism
   3) Applications of dielectric materials
10. What is meant by local field in dielectrics and how it is calculated for a cubical structure? Deduce Clausius – Mosottoi equation. **(JUNE 2011)**
11. What is ferroelectricity? Explain the hysteresis effect of it. Give a few examples and applications of ferroelectric materials. **(JUNE 2011)**

UNIT –V -MODERN ENGINEERING MATERIALS

PART- A

1. **What are metallic glasses? (JAN 2013)**
   Metallic glasses are the newly developed engineering materials which share the properties of both metals and glasses.
2. **What are the types of metallic glasses and mention few metallic glasses.**
   Metal- metalloid metallic glasses, Eg: Fe, Co, Ni: Bi, Si, P
   Metal-metal metallic glasses Eg: Ni, Nb
3. **State the structural properties of metallic glasses.**
   They do not have any crystal defects
   They have tetrahedral close packed structure
4. **What are the mechanical properties of metallic glasses?**
   They have high elasticity
   They are highly ductile.
5. **What are the electrical properties of metallic glasses?**
   Electrical resistivity is high and it does not vary much with temperature.
   Due to high resistivity, the eddy current loss is very small.
6. **What are the applications of metallic glasses?**
   They are used as reinforcing elements in concrete, plastic or rubber.
   They are used to make razor blades and different kinds of springs.
7. **What is the advantage of using metallic glasses as a transformer core material?**
   They possess low magnetic losses, high permeability, high saturation magnetization and extreme mechanical hardness.
8. **What are shape memory alloys?**
   Metallic alloys which have the ability to return to their original Shape or Size when subjected to appropriate thermal procedure are called SMAs.
9. **What is shape memory effect?**
   Metallic alloys which have the ability to return to their original Shape or Size when subjected to appropriate thermal procedure are called SMAs. This effect is called Shape memory effect
10. **What are the properties of shape memory alloys?**
    There is existence of two different solid phases with distinct crystal structures in SMA.
    They exhibit self healing effect.
11. **What are the applications of SMAs?**
    SMAs can act as actuators and sensors.
    Fibre composite SMAs are used to produce twist on the helicopter blades.
12. **What is glass transition temperature?**
    The temperature at which the transition from liquid to solid occurs is known as transition temperature.
13. **What are nano phase materials?**
    Nanophase materials are newly developed materials with grain size at the nanometre range.
14. **Mention different forms of nanomaterials.**
    Nanorods, Nanodots, Carbon nanotubes and Fullerenes.
15. **What are the two routes through which nano particles can be synthesized?**
    Top down approach
    Bottom up approach
16. **Mention few techniques for synthesis of nanophase materials.**
    Mechanical alloying, Electro-deposition, Inert gas condensation, Laser synthesis, Sol-gel technique
17. **What are the physical properties of nano materials?**

Melting point reduces with decrease in cluster size; Interparticle spacing decreases with decrease in grain size for metal clusters; Ionization potential changes with cluster size of the nanograins.

18. What are the mechanical properties of nano materials?

Higher moduli of elasticity and higher hardness; Higher hardness and mechanical strength; High ductility and superplastic behavior at low temperatures

19. What are the magnetic properties of nano materials?

Non-magnetic materials become magnetic when cluster size reduces to about 80 atoms; Ferromagnetic materials exhibit super paramagnetism at nanograin sizes.

20. Mention the applications of nanophase materials.

Nanoelectronic devices such as nanotransistors, ceramic capacitors for energy storage; Tiny permanent magnets of high energy products; Quantum dots, quantum wells and quantum wires

21. Define pseudo elasticity

It occurs in some types of SMA in which the change in its shape will occur even without change in its temperature.

22. What do you understand by Martensite and Austenite phases?

Martensite: It is an interstitial super solution of carbon in α – iron and it crystallizes into twinned structure.

Austenite: It is the solid solution of carbon and other alloying elements in γ- iron and it crystallizes into cubic structure.

23. What is two –way memory effect in SMA? (JUNE 2011)

The type of materials which produces spontaneous and reversible deformation just upon heating and cooling even without load are called two way shape memory alloy

24. What is non-linear optics?

The field of optics dealing with the non-linear behavior of optical materials is known as non-linear optics.

25. Name few non-linear optical phenomena.

Higher harmonic generation, Optical mixing, Optical phase conjugation and Soliton

26. What are non-linear materials?

The material in which optical properties depend on the intensity of light and they behave non-linearly are called non-linear optical materials.

27. What is meant by second harmonic generation?

In some non linear crystals which lack centre of symmetry, when intense radiation is passed through, the frequency of radiation is doubled.

28. What are biomaterials?

The materials which are used for structural applications in the field of medicine are known as biomaterials. They are used to make device to replace damaged or diseased body parts in human and animal bodies.

29. What are the types of biomaterials? Mention few biomaterials and their applications.

i. Ceramics biomaterials, Polymer biomaterials, Composite biomaterials

ii. Cobalt based alloys, Titanium, Stainless steel

iii. a) Stainless steel is a predominant alloy widely used in implant and orthopaedic applications

b) Protosal from case alloy used to make stem and head of implant hip endoprosthesis.

PART-B

1. What are nano phase materials? Explain how the physical properties vary with geometry. **(DEC 2012)**
2. What are nanophase materials? Discuss how mechanical and magnetic properties of nano materials vary with particle size.
3. Give the concept, properties and applications of metallic glasses.
4. How are metallic glasses prepared? Explain how the melt spinner device can be used to produce metallic glasses. **(MAY 2013)**
5. Explain the characteristics and applications of SMAs.
6. What are shape memory alloys? List out any four applications of SMAs. **(NOV 2012)**
7. Discuss the applications of nano materials in various fields.
8. Explain the origin of nonlinear optics. How are second harmonic waves generated?
9. Explain biomaterials and its modern applications in the field of medicine. **(DEC 2005)**