ELECTRICAL ENGINEERING MATERIALS – SEMESTER 6

Internal Test 1 – Solution

Subject Code: 10EE666

Answer any five full questions. Each Question carries 10 Marks.

1. Fermi Dirac distribution function : Distribution functions are the probability distributions used to describe the probability with which a particular particle can occupy a particular energy level. We are interested in checking the probability of an electron in an energy state of an atom. – (2 Marks)

   The Fermi Dirac expression is given by $f(E) = 1/ 1 + \exp(E - Ef/K_BT)$

   $K_B = 1.38 \times 10^{-23}\ JK^{-1}$ is the Boltzmann constant

   T = absolute temperature

   Ef = Fermi level or Fermi energy.

   Put E = Ef , f(E) = 1/1 + exp(Ef – Ef)/kBT) = 1/1+1 =1/2 - 4 Marks

   In intrinsic semiconductors, the Fermi level is situated in the middle of valence band and conduction band. In N type semiconductor, the Fermi level is situated near the conduction band. In P type semiconductor, the Fermi level is situated present near the valence band. Fermi Level is the level at which one can expect the electron to be present exactly 50% of the time. –(4 Marks.)

2. A fuse is a safety device consisting of a strip of wire that melts and breaks an electric circuit if the current exceeds a safe limit. A fuse consists of a metal strip of wire fuse element of small cross section compared to the circuit conductors mounted between a pair of electrical terminals and enclosed by a non – combustible housing. The fuse element is made up of zinc, copper, silver, aluminium or alloys to provide stable and predictable characeteristics. – (4 Marks)

Fuses have been used as essential safety devices from the early days of electrical engineering. Today there are thousands of different fuse deisgns which have specific current and voltage ratings, breaking capacity and response times, depending on the application. A fuse is an automatic means of removing power from a faulty system, often abbreviated to automatic disconnection of supply. Circuit breakers can be used as an alternative design solution to fuses. The time and current operating characteristics of fuses are chosen to provide adequate protection without needless interruption. Short circuits, overloading, mismatched loads or device failure are the prime reasons for fuse operation. (6 Marks).

3. Types of Resistors – Carbon composition and Wire wound

   Carbon composition Resistors – 5 Marks

   Wire wound Resistors – 5 Marks

   Carbon composition resistors – moulded, insulated moulded, cracked carbon resistors

   Moulded form – This is manufactured in both insulated and un insulated form. The raw materials used are carbon black, resin binder and refractory filling. Diagram.

   Insulated moulded form – A thermosetting plastic is moulded around some carbon composition resistors. The carbon and binder material are mixed but extra materials are also added to make the mix suitable for extrusion. Diagram.

   Cracked carbon – Here the decomposition of a suitable hydrocarbon vapour is done at 900 – 1100^0 C. The value of the resulting resistance is controlled by the pressure of the vapour and the temperature of firing. (5 Marks)

   Wire wound resistors – these are generally capable of dissipating appreciable amounts of power. The connecting wires are usually welded to the ends of the winding. diagram

   Lacquered – these resistors have a moisture proof layer of lacquer or organic varnish. A temperature of 150^0 C limits the maximum voltage.

Vitreous enameled – these resistors have a covering of vitreous enamel over the resistance wire. This provides excellent protection against moisture. (5 Marks)

4. When a current carrying conductor is placed in a magnetic field, a tranverse effect is obtained. This effect is called Hall effect. When a magnetic field is applied at right angles to the direction of the electric current an electric field is set up which is perpendicular to both the direction of electric current and the applied magnetic field.(2 Marks) Diagram – (3 Marks)

   Let a magnetic field Bz be applied in the positive z direction. According to Hall effect a force gets exerted on the charge carriers in the negative y – direction. This current I may be due to holes moving in the positive –x or due to free electrons moving in the negative – x direction through the semiconductor specimen. The current in an N – type specimen is carried almost fully by electrons. These electrons as a result of Hall effect, accumulate on side 1 which surface then gets negatively charged relative to side 2. Consequently a potential difference develops between surfaces 1 and 2 and is called Hall voltage(V_H). This Hall votage in an N-type semiconductor is positive at surface 2. In a P type specimen, the Hall voltage is positive at surface 1. These two results have been verified experimentally.(5 Marks)

5. <u>Magnetic flux density</u> : It is defined as the flux or lines of force passing per unit area through any substance through a plane at right angles to the direction of magnetic flux. It is represented by B and unit is Wb / m^2

   <u>Relative permeability</u> : It is the ratio of flux density (B) produced in that material to the flux density produced in vacuum by the same magnetizing force.(H). it is denoted by denoted by μ_r.

   <u>Susceptiblility</u> : The magnetic susceptibility depends on the nature of the magnetic material and on its state, temperature. The susceptibility of a sample may change on cold working.

Magnetic potential : The magnetic potential at any point within a magnetic field is measured by the work done in carrying a unit North pole from infinity to that point against the force of magnetic field.

Coercive force : It may be defined as the demagnetizing force which is necessary to neutralize completely the magnetism in an electromagnetic material after the value of magnetizing force becomes zero.

(2 Marks each. Total Marks : 10)

6. Prove that for a magnetic material : $B = \mu_0(M + H)$

Consider a solenoid.

Let l = Length of Solenoid, A = Area of cross – section

N = number of turns, I = Current through the solenoid

If the solenoid is placed in vacuum, the flux density will be $B_0=\mu_0 H$

(Where H = NI/l , H being the magnetizing force)

If the vacuum is replaced by a homogeneous magnetic medium, the flux density increase to $B = \mu_0\mu_r H$

Thus there will be an increase in flux density of

$B - B_0=\mu_0(\mu_r - 1)H=\mu_0 H'$

If I' is the corresponding increase in current, then we have H' = NI'/l = NI'A/lA

$H' = (\mu_r - 1)H = M$

$M/H = \Upsilon = \mu_r - 1$ where Υ is a dimensionless quantity and is defined as the magnetic susceptibility of the medium.

$B = B_0 + \mu_0 H' = \mu_0(1 + \Upsilon)H = \mu_0(1 + M/H)\ H$

$B = \mu_0(M + H)$ (10) Marks

7(a) Electron charge = 1.6×10^{-19} C

The current produced is given by $I = n_I e(\mu_e + \mu_h)AV/l = 2 \times 10^{19} \times 1.6 \times 10^{-19} (0.36 + 0.17) \times 10^{-4} \times 2/0.3 \times 10^{-3} = 1.13A$ (5) Marks

(b) Conductivity of Germanium, $\sigma_{ge} = n_I e(\mu_e + \mu_h)$

$n_I = 1/0.47 \times 1.6 \times 10^{-19}(0.42 + 0.20) = 2.145 \times 10^{-19}/m^2$ - (5) Marks