MACHAKOS UNIVERSITY

University Examinations for 2020/2021

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 304: ELECTRICAL ENGINEERING MATERIALS

DATE: 18/8/2021 **TIME: 2:00 – 4:00 PM**

INSTRUCTIONS:

- *This paper consists of Five Questions*
- *Question **One is Compulsory***
- *Attempt Any other Two Questions*
- *Make your answers Exact and concise*

QUESTION ONE (COMPULSORY) (30MARKS)

a) Discuss the *Thermal Classification* of *Solid Insulating Materials*, giving examples in each case. (7 marks)

b) Show that thermal conductivity in metals is better defined by *Wiedemann-Franz Law*

(3 marks)

c) The Fermi energy for Copper may be determined from the relation

$$W_F = \frac{h^2}{8m}\left(\frac{3n}{\pi}\right)^{2/3}$$

i) Show that (1.5marks)

$$W_F = 3.65x10^{-19}n^{2/3}eV$$

ii) Now the mobility of the electrons is $56cm^2/V/s$ and the free electrons per cubic meter is $= 5.86x10^{28}$. Determine the *Fermi Velocity* and the *Mean Free Path* of the electrons in silver. (3 marks)

iii) If there is one conduction electron per atom, the density of copper is $8920kg/m^3$ and its atomic weight is 63.54; determine the *Fermi Energy* at 0K (1.5marks)

d) The dielectric constant of Helium, measured at 0℃ and 1 atmosphere is $\varepsilon_r = 1.0000684$. Under these conditions, the gas contains $2.7x10^{25}$atoms per m^3. The Helium atom is subjected to a field of $10^6V/m$. From *First Principles* of Electronic polarization determine:

(i) Radius of electron cloud (atomic radius) (4 marks)

(ii) Displacement due to the applied field (3 marks)

e) Combined Polarization can be approximated by a linear representation. If the y intercept is assumed to be $8.0x10^{-4}$ and the slope is 0.6 per degree kelvin, determine the dipole moment and polarizability of the molecules from *First Principles*. The number of molecules can be taken as $2.5x10^{25}/m^3$ (5 marks)

f) For a permanent magnetic material, the hysteresis loop second quadrant BH($\frac{J}{m^3}$) product against B(T) can be given by

$$BH\left(\frac{J}{m^3}\right) = -2x10^5B^2 + 2x10^5B$$

Determine the maximum value of BH and the corresponding value of H (3 marks)

QUESTION TWO (20 MARKS)

One of the most important materials in *Electronic Engineering* are the Insulators

a) Giving examples, state and explain the various applications of *Insulating Materials* in Electronics Engineering (3 marks)

b) Discuss the *Modern Trends* in Insulating Materials (4 marks)

In Electrical Power Systems Engineering, Conducting Materials play a key role. That is, the entire power system network must embrace the conduction systems at generation, transmission, distribution and consumption levels.

c) Giving examples, state and explain the various applications of *Conducting Materials* in Electrical Power Systems (5 marks)

d) Discuss the Future Trends in Conducting Materials (3 marks)

e) The equation of motion of an electron in a metal under the influence of an electric field E is given by

$$-eE = m\frac{d\vartheta_D}{dt} + \frac{m\vartheta_D}{\tau_F}$$

Show that the effective conductivity of the metal may be given by

$$\sigma = \frac{\sigma_0}{1 + j\omega\tau_F}$$

Where σ_0 is the low frequency conductivity (5 marks)

QUESTION THREE (20 MARKS)

a) Show that

$$\chi_m = \mu_r - 1$$

Define all the symbols used (2 marks)

b) For a *Paramagnetic Material (PM),* show that (4 marks)

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

All the symbols used must be defined.

c) For a *Ferromagnetic Material (FM),* show that (4marks)

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

All symbols carry their usual meaning

d) Show that the *Antiferromagnetic Materials (AFM)* obey an *Extension of Curie Weiss Law (ECL)* at sufficiently high temperature. That is (4 marks)

$$\chi_m = \frac{2C}{T+\theta}$$

e) Using the relations in b)-c) above, explain the classification of Magnetic Materials, giving examples in each case. (3 marks)

f) In a material, an application of a magnetic field of $1.72x10^5 A/m$ causes a magnetic induction of $0.2162T$. Identify the type of Magnetic Material. (3 marks)

QUESTION FOUR (20MARKS)

a) Define *Oriental Polarization* (2 marks)

b) For a dielectric dipole, show that *Oriental Polarization* is given by

$$P_0 = N\alpha_0 E$$

All symbols carry their usual meaning (11marks)

c) There are $10^{27} HCl$ molecules per cubic meter in a vapor. The vapor is subjected to an electric field of $10^6 V/m$, the permanent dipole moment of HCl being $1.04 debye$ unit.

(i) Show that the parameter a that defines the permanent dipole moment is far less than unity for oriental polarization in this case (3 marks)

(ii) Determine *Oriental Polarizability* and *Oriental Polarization* (4 marks)

QUESTION FIVE (20MARKS)

a) Show that the *Internal Fields* in solid and liquid dielectrics can be defined by the relation given by

$$E_i = E + \frac{\gamma}{\varepsilon_0} P$$

All the symbols carry their usual meaning (5 marks)

b) For an elemental solid dielectric with internal fields,

i) Show that (6 marks)

$$\frac{N\alpha_e}{3\varepsilon_0} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2}$$

Explaining all the assumptions made. All symbols carry their usual meaning

ii) From bi) above, derive the *Lorentz-Lorenz Equation (LLE)* that is applicable in dielectric materials operating in the optical frequency range (2 marks)

c) A long narrow rod has an atomic density of $5 * 10^{28} atoms\ /m^3$ and each atom has a polarizability of$10^{-40} F/\ m^2$. When an axial field of 1V/m is applied, determine the *Internal Electric Field* from first principles. (2 marks)

d) For diamond, only Electronic Polarization is present. The refractive index is 2.42. Show that (3 marks)

$$N\alpha_e = 1.643x10^{-11}\frac{M}{\rho}$$