DEDAN KIMATHI UNIVERSITY OF TECHNOLOGY

UNIVERSITY EXAMINATION 2021/2022

SECOND YEAR FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING, BACHELOR OF SCIENCE IN TELECOMMUNICATION INFORMATION AND ENGINEERING & BACHELOR OF EDUCATION IN TECHNOLOGY (ELECTRICAL AND ELECTRONIC ENGINEERING)

EEE 1204/ETI 1204 MATERIAL SCIENCE

DATE: DECEMBER 2021 TIME: 2 HOURS

INSTRUCTIONS

i. This examination contains **FIVE** questions.
ii. **QUESTION 1** carries 30 marks while the **OTHER FOUR QUESTIONS** carry 20 marks.
iii. Attempt **QUESTION 1** and any other **TWO QUESTIONS**.
iv. All symbols have usual meaning unless otherwise stated.

QUESTION ONE (Compulsory) [30 Marks]

a) Explain briefly the difference between the following:
   i. Dielectric and superconductors. [**2 Marks]**
   ii. Self-interstitial defect and interstitial solid solution defect. **[2 Marks]**

b) Explain what is meant by anisotropy in material properties. **[1 mark]**

c) Briefly explain what determines the characteristic color of
   i) a metal, and **[1 Mark]**
   ii) a transparent non-metal **[1 Mark]**

d) Lead (Pb) metal has a face centered cubic crystal structure, atomic number = 82, atomic radius = 0.1750 nm and atomic mass 207.2 g/mol. Given that the Avogadro Number is $6.022 x 10^{23}$ atoms/mol;

   i) Give its electronic configuration. **Hint**: Use Diagonal Rule **[1 Mark]**
   ii) Sketch the unit cell, **[1 Mark]**
   iii) Determine its edge length *a* **[1 Mark]**
   iv) Determine the number of atoms in the unit cell **[1 Mark]**
   v) Determine the atomic packing factor, **[2 Marks]**

vi) Determine the theoretical density. **[2 Marks]**

e) Express the **[101]** direction into the Miller–Bravais index system for hexagonal crystals **[3 Marks]**

f) State any **FOUR** industrial applications of electrical properties. **[2 Marks]**

g) The size and shape of the hysteresis curve for ferromagnetic and ferrimagnetic materials is of considerable practical importance. Using a well labelled sketch of a hysteresis loop,

   i) State any **THREE** differences between a soft and a hard magnetic material. **[4 Marks]**

   ii) State any **ONE** application of the soft and hard magnetic materials. **[2 Marks]**

h) Consider a parallel-plate capacitor having an area of 2500 mm^2 and a plate separation of 2 mm, and with a material of dielectric constant 4.0 positioned between the plates. By taking permittivity of a vacuum as 8.85×10^{-12} F/m,

   i) Calculate the capacitance of the capacitor? **[2 Marks]**

   ii) Determine the electric field that must be applied for 8.0×10^{-9} C to be stored on each plate. **[2 Marks]**

QUESTION TWO **[20 Marks]**

a) What are the main reasons for adoption of composites as engineering materials? [**3 marks]**

b) Distinguish between fluorescence and phosphorescence? **[2 Marks]**

c) In terms of electron energy band structure, discuss the difference in electrical conductivity between metals, semiconductors, and insulators. **[3 Marks]**

d) Body centred cubic (BCC) crystal structure is one of the metallic structures.

   i) Using well-labelled sketch, derive an expression for the relationship between ***r*** and lattice parameter ***a***. **[2 Marks]**

   ii) Derive an expression for the atomic packing factor (APF). **[2 Marks]**

   iii) State at least **TWO** materials which have BCC crystal structure **[1 Mark]**

e) A BCC iron has lattice parameter of 0.2866 nm. Assuming that monochromatic radiation having a wavelength of 0.1790 nm is used and the order of reflection is 1, calculate;

   i) the interplanar spacing for the (220) set of planes, **[1.5 Marks]**

   ii) the diffraction angle for the (220) set of planes. **[2 Marks]**

f) Calculate the equilibrium number of vacancies per cubic meter in iron at 850°C. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density (at 850°C) and atomic weight for Fe are 7.65 g/cm^3 and 55.85 g/mol, respectively. Take Boltzmann's constant = 8.62×10^{-5} eV/atom·K and Avogadro number = 6.022×10^{23} atoms/mol. **[3.5 Marks]**

QUESTION THREE **[20 Marks]**

a) Using sketches, briefly explain the following defects:

   i) Grain boundary **[2 Marks]**

ii) Twin boundary **[2 Marks]**

b) Sketch the following Miller directions and planes.

i) $[\bar{1}21]$, $[213]$ **[2 Marks]**

ii) (122) (021) **[2 Marks]**

c) A cylindrical coil of wire made up of 200 turns is 20 cm long and can carry a current of 10 A. Based on the data provided;

i) Calculate the magnitude of the magnetic field strength H generated by the coil? **[1.5 Marks]**

ii) Compute the flux density B if the cylindrical coil is in a vacuum given that the permeability of a vacuum is 1.257×10^{-6} H/m. **[1.5 Marks]**

iii) Compute the flux density inside a bar of titanium that is positioned within the coil if the susceptibility for titanium $Xm = 1.81 \times 10^{-4}$. Comment on the answer in comparison to ii) above. **[2.5 Marks]**

iv) Compute the magnitude of the magnetization M. **[1.5 Marks]**

d) In respect to Bohr model on electronic structure of solids,

i) Explain the concept of quantized energies. **[2 Marks]**

ii) Determine the energy emitted and the wavelength of the photon emitted from hydrogen during an n=4 to n=2 electron transition. Take Planck's constant to be 6.626×10^{-34} Js and the Rydberg constant to be 2.18×10^{-18} J. **[2.5 Marks]**

iii) State the region in which the emitted light in ii) falls into in the electromagnetic spectrum **[0.5 Mark]**

<u>QUESTION FOUR [20 Marks]</u>

a) With aid of a sketch of a typical compound, describe how covalent bond is formed. **[2 marks]**

b) Explain the term metal alloy and explain the reason for alloying a pure element.[2 Marks]

c) In respect to electronic structure of atoms,

i) Illustrate the meaning of the terms' wave/particle duality [3 Marks]

ii) Calculate the de Broglie wavelength of an electron travelling at a velocity of 1.0×10^{7} ms^{-1} and has a mass of 9.109×10^{-28} g. [2 Marks]

d) A copper wire with a diameter of 3 mm, length of 2 m and electrical conductivity of 6.0×10^{7} $(\Omega \cdot m)^{-1}$ is use for electrical installation. Based on the data given;

i) Compute the resistance of a copper wire? [2 Marks]

ii) What would be the current flow if the potential drop across the ends of the wire is 0.05 V? [1.5 Marks]

iii) What is the current density? [2 Marks]

iv) What is the magnitude of the electric field across the ends of the wire? [1.5 Marks]

e) The fraction of non-reflected radiation that is transmitted through a 10-mm thickness of a transparent material is 0.90. If the thickness is increased to 20 mm, what fraction of light will be transmitted? [4 Marks]

QUESTION FIVE [20 Marks]

a) A solid solution consists of atoms of at least two different types. From this statement,
   i) Using a neat sketch, explain what you understand by the term substitutional solid solution **[1.5 Marks]**
   ii) Explain the **FOUR** conditions that favour formation of substitutional solid solutions **[4 Marks]**

b) i) Calculate the drift velocity of electrons in germanium at room temperature and when the magnitude of the electric field is 1000 V/m and mobility of electrons is 0.38 m^2/V-s **[2 Marks]**

   ii) Under these circumstances, how long does it take an electron to traverse a 25-mm length of crystal? **[2 Marks]**

c) Cobalt element has atomic mass of 58.9 g/mol, density of 8.90g/cm^3 and a net magnetic moment per atom of 1.72 Bohr magnetons. By taking the permeability of a vacuum μ_0 and Bohr magneton μ_B of $4\pi \times 10^{-7}$ (1.257×10^{-6}) H/m and 9.274×10^{-24} A.m^2 respectively and Avogadro number to be 6.022×10^{23} atoms/mol; calculate:

   i) the saturation magnetization, [2.5 Marks]
   ii) the saturation flux density for cobalt [1.5 Marks]

d) At room temperature the electrical conductivity of PbTe is 500 $(\Omega\text{-m})^{-1}$, whereas the electron and hole mobilities are 0.16 and 0.075 m^2/V-s, respectively. Compute the intrinsic carrier concentration for PbTe at room temperature. [3 Marks]

e) Consider the section of a (110) plane within an FCC unit cell represented in Figures 5e (a) and (b). Calculate the planar density of that plane. Take R = 0.1241nm. (R is the radius of the atom) **[3.5 Marks]**

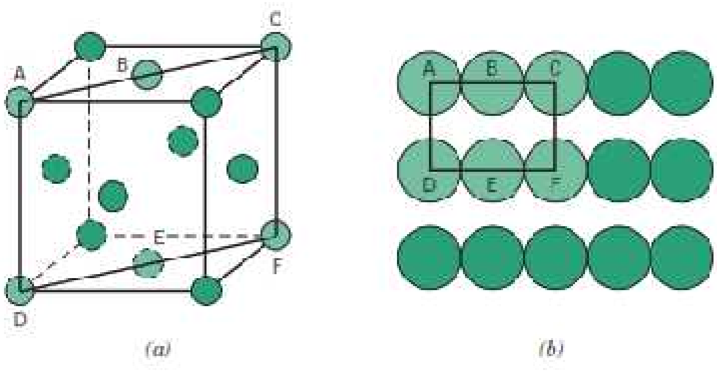

Figure 5e

END…ALL THE BEST…