UNIVERSITY OF GHANA

BSc. (ENG) MATERIALS SCIENCE & ENGINEERING

FIRST SEMESTER EXAMINATION: 2018/2019

MTEN 313: Electrical, Magnetic and Optical Properties of Materials (3 Credits)

Answer All Questions **Time Allowed: 3 Hours**

1.

(a) When cooled below a temperature called the Curie temperature, the magnetization of a piece of ferromagnetic material spontaneously divides into many small regions called magnetic domains. The magnetization within each domain points in a uniform direction, but the magnetization of different domains may point in different directions. Why do magnetic domains form? [10 Marks]

(b) When a ferromagnetic material is magnetized in one direction and reversed, it will not relax back to zero magnetization when the imposed magnetizing field is removed causing a phenomena called hysteresis. There is considerable variation in the hysteresis of different magnetic materials and this is exploited in a number of applications for memory devices, transformers, recording heads etc. Discuss the origin of magnetic hysteresis using schematic diagrams. [10 Marks]

2.

(a) Discuss your understanding of the band theory with reference to conductivity and how does the understanding of the band theory help in distinguishing between the categories of solids (conductors, semiconductors and insulators). [10 Marks]

(b) As a materials technologist you have been tasked to design and select a given dielectric material capable of giving high capacitance for energy/charge storage. Using relevant equations with schematic diagrams discuss your design variables. [10 Marks]

3.

(a) Light can interact with matter in three ways: absorption, transmission, and reflection. Discuss in detail light's interaction with matter. [10 Marks]

(b) Discuss the differences in the origins of color in metals and semiconductors and how this is exploited especially semiconductor device design. [5 Marks]

(c) LASER stands for Light Amplification by Stimulated Emission of Radiation
With aid of schematic diagrams how different is Spontaneous emission from Stimulated Emission? [5 Marks}

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4.

(a) There are a few materials for which the resistivity at a very low temperatures, abruptly plunges from a finite value to one that is virtually zero and remains there upon further cooling. They are called superconductors, and the temperature at which they attain superconductivity is called the critical temperature T_C. Explain or discuss the quantum mechanical understanding of the BCS theory. [10 Marks]

(b) Sketch the resistivity vs. temperature curve for conductors and superconductors and discuss the origin of resistivity in conductors. [10 Marks]

5. The electrical conductivity is controlled by controlling the number of charge carriers in the material (n) and the mobility or "ease of movement" of the charge carriers (μ).

(a) Explain in detail to a layman the occurrence of resistance/resistivity in materials. [5 Marks]

(b) The electrical resistivity of pure silicon is $2.3 \times 10^3\ \Omega m$ at room temperature (27 °C ~ 300 K). Calculate its electrical conductivity at 200 °C (473 K). Assume that the E_g of Si is 1.1 eV; $k_B = 8.62 \times 10^{-5}$ eV/K and the conductivity 'σ' is given by:

$$\sigma = C.\exp\left(\frac{-E_g}{2k_BT}\right)$$

[15 Marks]