School of Computing and Engineering Sciences

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONIC ENGINEERING)

End of Semester Examination

BEE 2202: Electrical Materials

Date: 14TH March 2023 **Time: 13:00-16:00 Hours**

Instructions: Answer Question **ONE** and any other **TWO** Questions

QUESTION ONE

a) Using Hund's rules, develop an expression of the ground term symbol ($^{2S+1}L_J$) of a carbon atom (p^2 configuration), whose electronic configuration is $1s^2$, $2s^2$, $2px^1$, $2py^1$, given the orbital angular momentums of the two electrons in the P-subshell are l_1=1 and l_2=0, whereas their respective spin angular momentums are s1=+1/2 and s2=+1/2. The different atomic states are shown in Table 1(b). **(7mrks)**

Table 1(b)						
L-Value	0	1	2	3	4	5
Atomic State	S	P	D	F	G	H

b) Using illustrative carbon-hydrogen frameworks, explain the information about the structure of the compound, which is provided by the following features of a ^{1}H Nuclear Magnetic Resonance (NMR) spectrum

i. Number of signals **(2mrks)**

ii. Position of signals **(2mrks)**

iii. Intensity of signals **(2mrks)**

iv. Spin-Spin splitting of signals **(2mrks)**

c) State and explain the five postulates of quantum mechanics that can be followed in a step-by-step procedure when solving a quantum mechanical problem **(7mrks)**

d) With the aid of a well-labelled diagram, describe how Laser Diodes are applied in the functioning of Laser beam Printers **(8mrks)**

QUESTION TWO

a) Using the selection rules that predict transition between different energy levels and whether atomic states in spectra are allowed or not, develop the atomic spectra for hydrogen atom in a Grotrian diagram. Note that the electronic configuration of hydrogen atom is 1s and has a term symbol, $^2S_{1/2}$. The 2p orbitals of this atom have the term symbols $^2P_{1/2}$ and $^2P_{3/2}$, whereas the d orbitals have the term symbols $^2D_{3/2}$ and $^2D_{5/2}$. **(6mrks)**

b) Considering the four major informational features of ^{1}H NMR spectrum, extract and interpret conclusively, the ^{1}H NMR spectrum diagram shown in Fig. 2(c). **(9mrks)**

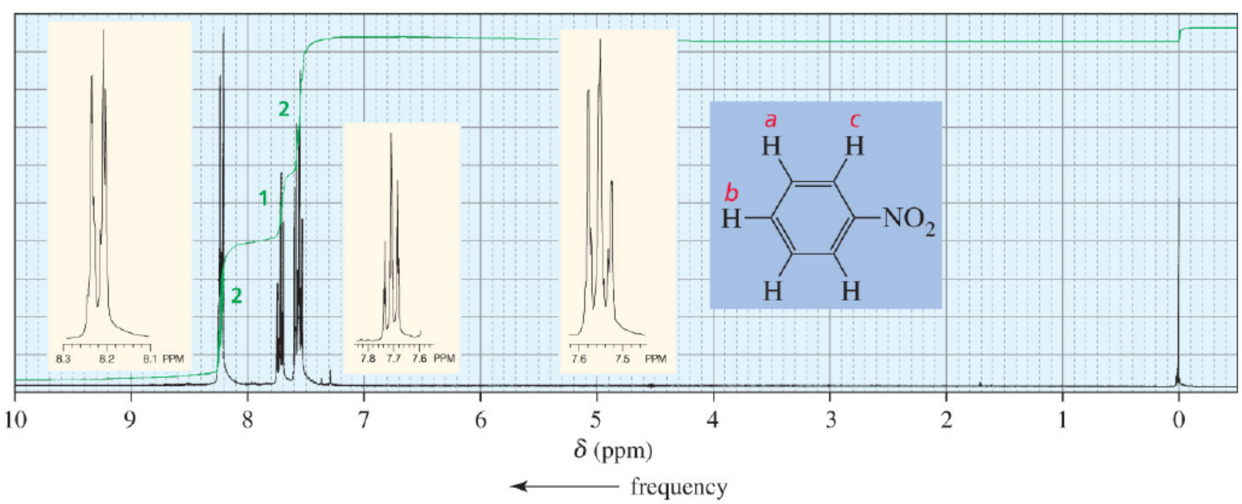

Fig. 2(c)

QUESTION THREE

a) Two electrons are present in two orbitals of a P-subshell. The spin angular momentums of these electrons are s_1 =+1/2 and s2=+1/2. Using the concept of coupling of their angular momenta (s-s coupling), compute their total Spin angular momentum (S) **(5mrks)**

b) Starting with the classical wave equation shown below, derive the Schrodinger wave equation in three-dimension i.e. $\psi(x, y, z)$ **(15mrks)**

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

QUESTION FOUR

a) Photo-detectors (photodiodes) are widely used in development of solar cells/ panels. Consider an earth satellite that has on board 12-V battery which supplies a continuous current of 0.5A. Solar cells are used to keep the battery charged. The solar cells are illuminated by the sun for 12 hours in every 24 hours. If during exposure, each cell gives 0.5V at 50mA, determine the number of cells required. **(8mrks)**

b) Discuss Light Emitting Diodes (LEDs) under the following dimensions:

i. Fabrication materials and theory of operation **(4mrks)**

ii. Construction **(4mrks)**

iii. Application in seven segment LED displays **(4mrks)**

QUESTION FIVE

The mathematical expression of the Kronig-Penney-model is given by the following equation and illustrated in Fig. 5, with a period of c=a+b.

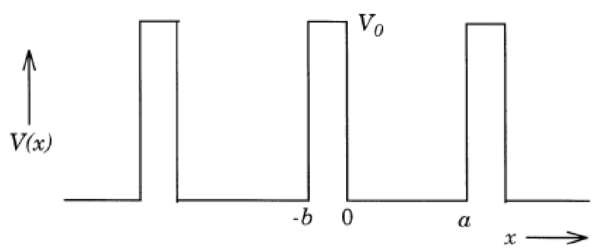

Fig. 5

$$V(x) = V_0; \qquad -b < x < 0$$

$$= 0; \qquad 0 < x < a$$

a) Provide the Schrodinger equation for this periodic mathematical expression and consider the resulting coefficients to deduce its general solution **(4mrks)**

b) Define and apply a translation operator $\hat{T}$ that shifts the wave function by a distance c, and hence show that a one-dimensional lattice is a ring of N atoms, modeled by the function y(x) such that; **(3mrks)**

$$y(x) = y(x + Nc)$$

c) Apply the Born-von Karmen boundary condition, in the resulting wave function of part (b) above, and hence show that any function y(x) satisfying the resultant equation can be written in the form of Bloch's theorem:

$$\psi(x) = u(x)e^{ikc}$$

Where, u(x) is a periodic function with period c, $e^{ikc} = t$, and $k = 2\pi l/Nc$ **(3mrks)**

d) By applying the conditions $\psi_1(0) = \psi_2(0)$; $u(-b) = u(a)$; and $u'(-b) = u'(a)$, obtain the numerical solutions to the general solutions of part (a) (Kronig-Penney-model), and plot the allowed values for $F(\varepsilon)$, where $\varepsilon = E/V_0$, between +1 and -1, with $r = b/a = 0.20$ and $A = (2mV_0)^{1/2}/\hbar = 10$ to demonstrate distribution of allowed energies in a band structure of crystalline solids, the basis of which classifies electrical materials as conductors, insulators and semiconductors. **(10mrks)**