Strathmore UNIVERSITY

SCHOOL OF COMPUTING AND ENGINEERING SCIENCES (SCES)
BACHELOR OF ELECTRICAL AND ELECTRONICS ENGINEERING
END OF SEMESTER EXAMINATION
BEE 2202: ELECTRICAL MATERIALS

DATE: **12th March 2025** Time: **08:30-11:30 Hours**

Instructions

1. This examination consists of **FIVE** questions.
2. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.

Q1. (a) (i) What is an atomic number (**1mks**)

(ii)What is the emission spectrum of a chemical element? (**1mks**)

(b) (i) Radiation with wavelength 300 nm is incident on a silver surface. Will photoelectrons be observed? (**3mks**)

(ii) Sodium has a work function of 2.46 eV. Will photoelectrons be observed? (**2mks**)

(iii) When a 180-nm light is used in an experiment with an unknown metal, the measured photocurrent drops to zero at potential of 0.80 V.

Determine the work function of the metal and its cut-off frequency for the photoelectric effect. (**3mks**)

Given that $hc = 1240\ eV.nm,\ \Delta Vs = 0.8\ V,\ \ h = 4.136 * 10^{-15}\ eV.s$

(c) Draw the Orbital filling Diagrams for Carbon and Oxygen with Z= 6 and 8 (**2mks**)

(d) (i) Determine the number of **^{1}H** NMR signals. (**3mks**)

$$\mathrm{CH_3 - O - CH_3} \qquad \mathrm{CH_3CH_2 - CI} \qquad \mathrm{CH - O - CH_2CH_3}$$

(ii) What is spectroscopy? (**1mk**)

(iii) Define Nuclear Magnetic Resonance (NMR) Spectroscopy, state two common types of NMR Spectroscopy and the source of energy in NMR. (**3mks**)

(e) Does the function shown below represent an acceptable wave function? (**5mks**)

$$\phi(x) = \begin{cases} sin\left(\frac{\pi x}{3}\right), 0 < x < 3 \\ 0, \ Otherwise \end{cases}$$

(f) With the aid of a clear and well labelled simple circuit diagram of an LED, explain its working or operation. **(3mks)**

(g) (i) Define density of states. **(1mk)**

(ii) Name the bulk properties that depend on this function. **(2mks)**

Q2. (a) State the four conditions that an acceptable quantum mechanical wave function must satisfy. **(4mks)**

(b) Starting with the classical wave equation shown below, derive the Schrodinger wave equation in three-dimension i.e. $\psi(x, y, z)$ **(11mks)**

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

Q3. (a) (i) Define Lattice Dynamics. **(1mk)**

(ii) Name any two applications areas of lattice dynamics **(2mks)**

(b) (i) State the two conditions that must be met for Laser oscillation to occur. **(2mks)**

(ii) Define and explain Laser pumping **(4mks)**

(c) With the help of a clear and well labelled diagram, explain the operation of a laser printer.

(6mks)

Q4 The mathematical expression of the Kronig-Penney-model is given by the following equation and illustrated in Fig. 3, with a period of c=a+b.

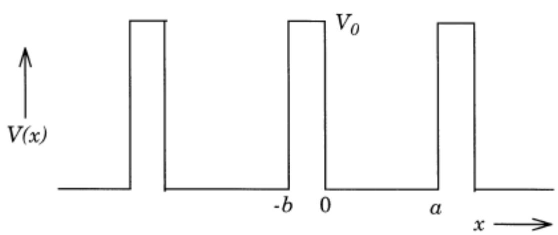

Fig. 3

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

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

(a) Provide the Schrodinger equation for this periodic mathematical expression and consider the resulting coefficients to deduce its general solution. **(6mks)**

(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; **(3mks)**

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

(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 $k = 2\pi l/Nc$ **(6mks)**

Q5. (a) Draw a well labelled block diagram of an LED based spectrophotometer (**5mks**)

(b) Explain the three general rules that describe the splitting patterns commonly seen in the ^{1}H NMR spectra of organic compounds. (**3mks**)

(c) Photodetectors (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. **(7mks)**