UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE (GENERAL) DEGREE LEVEL III (SEMESTER I)

EXAMINATION – OCTOBER 2022

Subject: PHYSICS

Course Unit: PHY 3114

Part II Time: 02 hours & 30 minutes

Answer FIVE (05) Questions only.

(All symbols have their usual meaning)

Planck's constant, $h = 6.626 \times 10^{-34}$ Js

Avogadro's number, $N_A = 6.022 \times 10^{23}$

Speed of light, $c = 3 \times 10^{8}$ ms^{-1}

1 eV = 1.602×10^{-19} J

Boltzmann constant, $k_B = 1.38 \times 10^{-23}$JK^{-1}

Mass of an electron, $m_e = 9.1 \times 10^{-31}$ kg

Charge of the electron = 1.602×10^{-19} C

1 a.m.u = 1.66×10^{-27} kg

1.

(a) Write down Bragg's law naming all the terms. **[05 marks]**

(b) Niobium has a FCC crystal structure. The angle of diffraction for the first order reflection from (2 1 1) set of planes occurs at 76°, when the monochromatic x-radiation used has a wavelength of 0.165 nm.

(i) Calculate the interplanar spacing for the set of planes (2 1 1). **[08 marks]**

(ii) Find the lattice constant of the unit cell of Niobium crystal. **[06 marks]**

(iii) Find the radius of the Niobium atom. **[06 marks]**

2.

(a) What is meant by carrier concentration? **[03 marks]**

(b) Drive an expression for the conductivity of an intrinsic semiconductor. Name all the terms. Hence, write down the equation for the resistivity of the intrinsic semiconductor. **[12 marks]**

(c) The resistivity of intrinsic semiconductor specimen at room temperature is 2×10^{-4} Ωm. If the mobility of electrons is 6 m^2/V sec and the mobility of holes is 0.2 m^2/V sec. Calculate the intrinsic carrier concentration. **[10 marks]**

3. A student takes a quiz in his physics exam. The quiz has N number of questions. He did not study for the quiz, so he guesses independently on every question. The probability of guessing a correct answer is $\boldsymbol{p}$ and the probability of guessing a wrong answer is $\boldsymbol{q}$. You may use the Binomial distribution function, $W_n(N)$, to answer following questions.

(a) What is the probability of guessing $\boldsymbol{n}$ number of questions correctly? **[05 marks]**

(b) Derive an expression for the mean number of questions, $\bar{\boldsymbol{n}}$, that the student could guess correctly. **[08 marks]**

(c) Assume that there are 10 multiple-choice questions in the quiz. If there are four possible choices for each question and only one of them is correct, what is the probability that the student answers only two questions correctly by only guessing? **[06 marks]**

(d) If the quiz consists of 10 questions with 4 True-False questions and 6 multiple choice questions with 4 possible choices for each, find the probability that the student answers exactly 1 question correctly by using guessing only. **[06 marks]**

4.

(a) The probability of finding a system in state r having energy E_r when it is in thermal equilibrium with a heat reservoir at temperature T according to Canonical distribution is given as follows. $P_r = \frac{e^{-\beta E_r}}{Z}$. Write down the partition function Z and state briefly, in words, what Z represents. **[04 marks]**

(b) Show that the mean energy $(\overline{E})$ of an isolated system in equilibrium with a heat reservoir at absolute temperature T is given by $\overline{E} = -\frac{1}{Z}\frac{\partial Z}{\partial \beta}$, where Z is the partition function of the system. **[06 marks]**

(c) Consider an isolated atom which has two energy levels. The energy of the lower level is E_1 and its degeneracy is g_1. The energy of the upper level is E_2 and its degeneracy is g_2. The atom is in thermal equilibrium with a heat reservoir at temperature T.

i) Write down the partition function of the system. **[05 marks]**

ii) What is the probability of finding the atom in the lower energy level with energy E_1. **[04 marks]**

iii) Obtain an expression for the mean energy of the system. **[06 marks]**

5.

(a) (i) State the de Broglie equation for matter waves. **[03 marks]**

(ii) Determine the de Broglie wavelength of an electron that has been accelerated through a potential difference of 100 eV. **[07 marks]**

(b) A particle is traveling along the x-direction with momentum p.

(i) State Heisenberg's uncertainty principle in mathematical form, describing each term. **[03 marks]**

(ii) Show that a similar uncertainty relation holds for energy and time. **[05 marks]**

(c) In an experiment, a beam of electrons traveling in x-direction with momentum p_0 incident on a single slit of width d. Show that the uncertainty relation holds when the beam produces a diffraction pattern on a screen placed at a distance D from the slit. **[07 marks]**

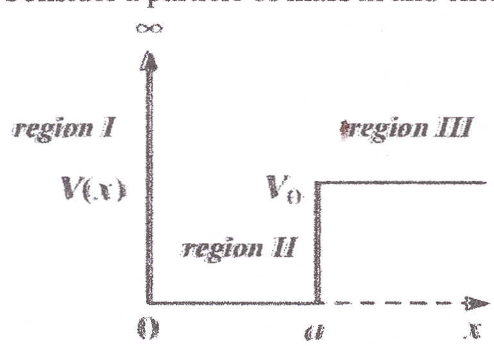
6.

(a) The general 1-D expression of time-independent Schrodinger equation is given below.

$$\left[\frac{-\hbar^2}{2m}\frac{d^2}{dx^2} + V(x)\right]\psi(x) = E\psi(x)$$

Describe what each term represents. **[04 marks]**

(b) Consider a particle of mass m and energy $E\,(< V_0)$ in a 1-D potential as shown in the figure.



$$\begin{cases} V = \infty\,; x < 0 & (region\ I) \\ V = 0\,;\ 0 \le x \le a & (region\ II) \\ V = V_0\,;\ x > a & (region\ III) \end{cases}$$

(i) Write down the Schrodinger equation for the two regions *II* and *III*. **[04 marks]**

(ii) Describe, briefly, the particle's existence in the region *I*, where $x < 0$. **[02 marks]**

(iii) Solve the two equations stated in part (i) and derive physically acceptable solutions. Describe, briefly, the behaviour of the particle in regions *II* and *III*. **[06 marks]**

(iv) Write down the boundary conditions and use them to obtain the general solution of the wave functions. **[05 marks]**

(v) Show that the bound state energies ($E < V_0$) are given by $\tan\left(\frac{\sqrt{2mE}\,a}{\hbar}\right) = -\sqrt{\frac{E}{V_0 - E}}$ **[04 marks]**

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