UNIVERSITY OF RUHUNA

B.Sc. General Degree Level III (Semester I) Examination – September/October 2018

Subject: PHYSICS

Course Unit: PHY 3114

Time: 02 hours & 30 minutes

Part II

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}

eV = 1.602×10^{-19} J

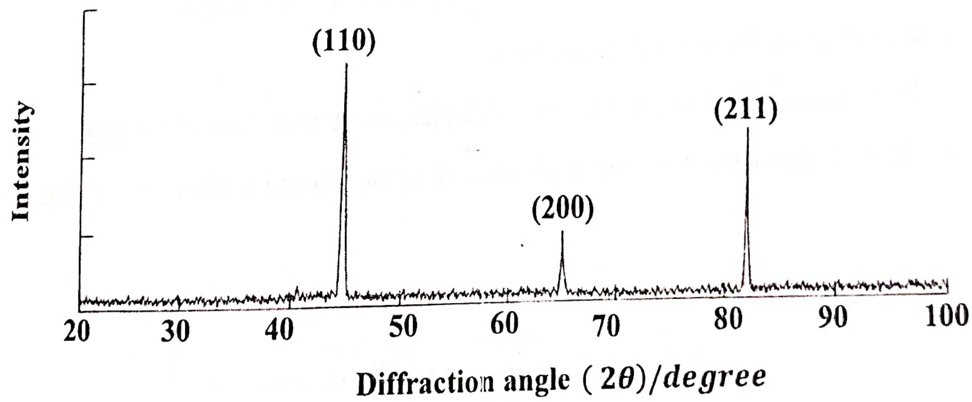
Boltzmann constant, $k_B = 1.38 \times 10^{-23}$ JK^{-1}

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

1 a.m.u = 1.66×10^{-27} kg

PART A

1. The figure below shows first order x-ray diffraction pattern for iron (**Fe**). Wavelength of the monochromatic x-radiation is 0.154 nm. The three peaks (110), (200) and (211) occurs at diffraction angle 45°, 65° and 82°, respectively



(a) Compute the interplanar spacing for second set of planes. **[05-marks]**

(b) Determine the lattice parameter for **Fe**. **[05-marks]**

(c) X-ray diffraction reveals that Fe forms cubic unit cell. Calculate the volume and mass of the cell. The density of Fe is 7.83×10^3 kg/m^3. **[05-marks]**

(d) Molecular weight of **Fe** is 55.85×10^{-3} kg. Determine the type of cubic unit cell whether (SC, FCC or BCC). **[05-marks]**

(e) Find the radius of a **Fe** atom. **[05-marks]**

2.

(a) Sketch the Fermi levels of p-type and n-type semiconductors. [06-marks]

(b)

i) What is an extrinsic semiconductor? [03-marks]

ii) Write down the equation for conductivity of an extrinsic semiconductor, defining all terms. [04-marks]

iii) Obtain an expression for resistivity of an intrinsic semiconductor. [04-marks]

iv) Calculate the resistance of an intrinsic semiconductor rod at room temperature, which is 2 cm long, 1 mm wide and 1 mm thick. Concentration of intrinsic carriers at room temperature is 2×10^{19} m^{-3} and mobilities of electrons and holes are 0.39 and 0.19 $m^2V^{-1}s^{-1}$, respectively. [08-marks]

3. Consider the random walk problem in one-dimension. Assume that the drunk takes steps of equal length L. Probabilities of taking a step to the right and to the left are p and q, respectively.

(a) Write down the probability, $W_N(n_1)$, of taking n_1 steps to the right and n_2 steps to the left in a total of N steps. [05-marks]

(b) Find the mean number of steps taken to right $(\overline{n}_1)$ in a total of N steps. [05-marks]

(c) Obtain an expression for mean displacement. [05-marks]

(d) If $L = 0.25$ m and $p = 0.6$ calculate the mean displacement after total of 60 steps. [05-marks]

(e) What is the probability that the dunk will again be at the initial location after taking 10 steps? [05-marks]

$$\left(\text{Note: } np^n = p\frac{\partial p^n}{\partial p} \text{ and } \sum_{n=0}^{N} W_N(n) = (p+q)^N\right)$$

4.

(a) State ***Canonical distribution.*** [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) The energy of a one-dimensional simple harmonic oscillator is given by $E_n = \left(n + \frac{1}{2}\right)\hbar\omega$.

Quantum number n can assume the possible integer values $n = 0, 1, 2, 3, \ldots\ldots\infty$ and ω is the angular frequency of the oscillator. Suppose that such an oscillator is in thermal contact with a heat reservoir at low temperature T, so that $\frac{kT}{\hbar\omega} << 1$.

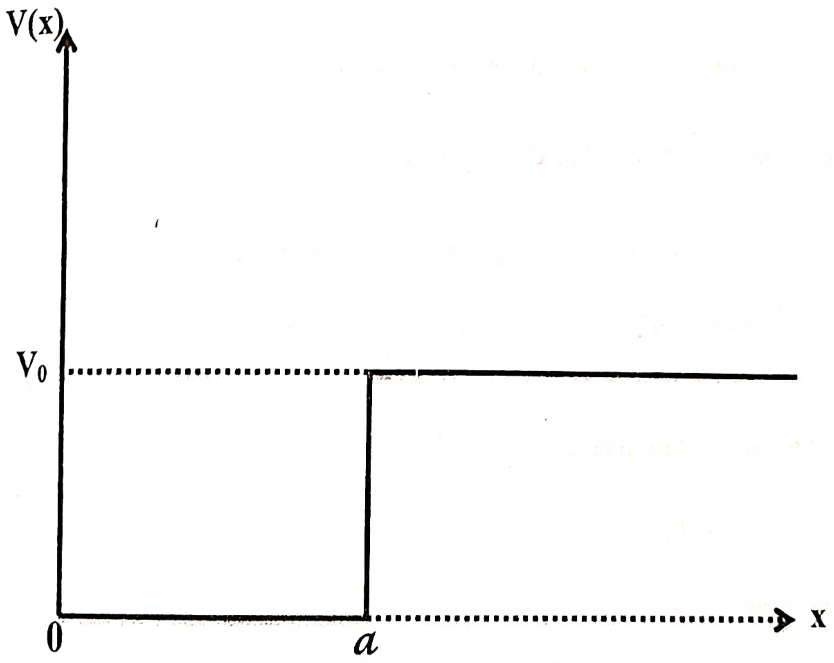
i) Find the ratio of, the probability of the oscillator being in the first excited state to the probability of its being in the ground state. **[05-marks]**

ii) Write the partition function of the system. **[05-marks]**

iii) Assuming that only the ***ground state*** ($n = 0$) and ***first excited state*** ($n = 1$) are appreciably occupied, find the mean energy of the oscillator as a function of the temperature T.

[05-marks]

5. (a) An electron of mass m is confined to a one-dimensional potential as shown in the figure. Consider that the electron energy $E > V_0$.



i) Solve the Schrödinger equation for regions, $0 < x < a$ and $x > a$. **[06-marks]**

ii) Find physically acceptable solutions for the two regions. **[04-marks]**

iii) What is probability of finding the electron in the region $x > a$. **[05-marks]** (b). Energy of a particle in one dimensional force free region of length L at quantum state n is given by $E_n = \frac{n^2h^2}{8mL^2}$. Write down the energies of the electron at the first excited state and the ground state in the bounded region $0 < x < 10$ fm. Hence, find the energy and wavelength of the photon emitted when electron undergoes a transition from first excited state to the ground state. In what region of the electromagnetic spectrum does this wavelength belong?

[10-marks]

6.

(a). Consider two eigen functions ψ_1 and ψ_2 corresponding to eigen values λ_1 and λ_2. Discuss characteristics of ψ_1 and ψ_2 under following conditions.

i) $\lambda_1 = \lambda_2$

ii) $\lambda_1 \neq \lambda_2$

[04-marks]

(b). Superposition of two orthonormal eigen functions $\psi_1(x)$ and $\psi_2(x)$ can be written as

$\psi(x) = C[\psi_1(x) + \psi_2(x)]$. Show that $C = \frac{1}{\sqrt{2}}$ if $\psi(x)$ is normalized.

[06-marks]

(c). Consider following relationships of a angular momentum operator $\hat{\vec{L}}$.

$\hat{L}_x = \hat{y}\hat{p}_z - \hat{z}\hat{p}_y$, $\hat{L}_y = \hat{z}\hat{p}_x - \hat{x}\hat{p}_z$, $\hat{L}_z = \hat{x}\hat{p}_y - \hat{y}\hat{p}_x$ and $\hat{L}^2 = \hat{L}_x^2 + \hat{L}_y^2 + \hat{L}_z^2$

i) Write down the commutation relation $[\hat{x}, \hat{p}_x]$.

[02-marks]

ii) Show that $[\hat{L}_x, \hat{L}_y] = i\hbar\hat{L}_z$.

[05-marks]

iii) Show that $\hat{L}^2$ operator commutes with $\hat{L}_x$ operator.

[05-marks]

iv) If $Y(\theta,\phi)$ is an eigen function of $\hat{L}^2$, write down the eigen value equation for $\hat{L}^2$ operator. Hence, define the eigen values of the $\hat{L}^2$ operator.

[03-marks]