Indian Forest Service
(Main) Exam, 2021

ZCVB-B-PHY

PHYSICS
Paper – II

Time Allowed : **Three** Hours

Maximum Marks : **200**

Question Paper Specific Instructions

Please read each of the following instructions carefully before attempting questions :

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*

*Questions no. **1** and **5** are **compulsory**. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections A and B.*

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

*Answers must be written in **ENGLISH** only.*

Useful Constants :

Mass of proton	$= 1{\cdot}673 \times 10^{-27}$ kg
Mass of neutron	$= 1{\cdot}675 \times 10^{-27}$ kg
Mass of electron	$= 9{\cdot}11 \times 10^{-31}$ kg
Planck constant	$= 6{\cdot}626 \times 10^{-34}$ Js
Boltzmann constant	$= 1{\cdot}380 \times 10^{-23}$ JK^{-1}
Bohr magneton (μ_B)	$= 9{\cdot}273 \times 10^{-24}$ A m^2
Nuclear magneton (μ_N)	$= 5{\cdot}051 \times 10^{-27}$ JT^{-1} (A m^2)
Electronic charge	$= 1{\cdot}602 \times 10^{-19}$ C
Atomic mass unit (u)	$= 1{\cdot}660 \times 10^{-27}$ kg
	= 931 MeV

g_s^p	$= 5{\cdot}5855\ \mu_N$	m(p)	$= 1{\cdot}00727$ u
m(n)	$= 1{\cdot}00866$ u	m($^4_2$He)	$= 4{\cdot}002603$ u
m($^{12}_6$C)	$= 12{\cdot}00000$ u	m($^{87}_{38}$Sr)	$= 86{\cdot}908893$ u
m($^2_1$H)	$= 2{\cdot}014022$ u	m($^3_1$H)	$= 3{\cdot}0160500$ u
m($^{16}_8$O)	$= 15{\cdot}999$ u	1 eV	$= 1{\cdot}60 \times 10^{-19}$ J
$\hbar$	$= 1{\cdot}05 \times 10^{-34}$ Js		
$\hbar c$	= 197 eVnm		

SECTION A

Q1. (a) A stream of electrons, each of energy E = 3 eV, is incident on a potential barrier of height V = 4 eV. The width of the barrier is 20 Å. Calculate the percentage transmission of the beam through the barrier. *8*

(b) Use the uncertainty principle to estimate

(i) The ground state radius of the hydrogen atom, and *4*

(ii) The ground state energy of the hydrogen atom. *4*

(c) A beam of electrons enters a uniform magnetic field of flux density 1·2 tesla. Calculate the energy difference between electrons whose spins are parallel and antiparallel to the field. *8*

(d) A substance shows a Raman line at 4567 Å when exciting line 4358 Å is used. Find the wavelengths of Stokes and anti-Stokes lines for the same substance when the exciting line 4047 Å is used. *8*

(e) Prove that

$$[J^2, J_y] = 0.$$ *8*

Q2. (a) Use WKB method to estimate the energy levels of a one-dimensional harmonic oscillator. *10*

(b) Find the eigenvalues and eigenstates of the spin operator $\vec{S}$ of an electron in the direction of unit vector $\vec{n}$. Assume that $\vec{n}$ lies in the xz-plane using spin matrices. *15*

(c) Describe and explain different types of coupling in atoms. Deduce the various interaction energy terms for L – S coupling. *15*

Q3. (a) (i) Derive the Schrodinger time-independent wave equation for matter waves.

(ii) An electron is confined to move in a one-dimensional potential well of length 5 Å. Find the quantized energy values for the three lowest energy states. *15*

(b) The zero point energy of the ground state of N_2 is 1176 cm^{-1} and that of its lowest excited state is 727 cm^{-1}. The energy difference between the minima of the two potential energy curves is 50,206 cm^{-1}. What is the energy of the $v' = 0 \rightarrow v'' = 0$ transition and its corresponding wavelength in cm ? *10*

(c) State the Franck – Condon principle and give its wave-mechanical interpretation. How does it help in understanding the intensity distribution in the vibrational structure of the electronic transitions of a diatomic molecule ? *15*

Q4. (a) To illustrate the idea that the zero point energy gets larger by going from macroscopic to microscopic systems, calculate the zero point energy for a particle in an infinite potential well for the following three cases :

(i) A 100 g ball confined on a 5 m long line.

(ii) An oxygen atom confined to a 2×10^{-10} m lattice.

(iii) An electron confined to a 10^{-10} m atom. *15*

(b) Determine the possible terms of a one-electron atom corresponding to n = 3 and compute the angle between $\vec{L}$ and $\vec{S}$ vectors for the term $^2D_{5/2}$. *10*

(c) Explain 'Lamb Shift' and describe the experimental arrangement to observe it. What is its importance ? *15*

SECTION B

Q5. (a) Assuming that protons and neutrons possess equal masses, calculate how many times nuclear matter is denser than water if nuclear radius is given by $1{\cdot}2 \times 10^{-15}\ A^{1/3}$ m, where A is the mass number. *8*

(b) A sample of uranium emitting α-particles of energy 4·18 MeV is placed near the ionization chamber. Assuming that only 10 particles per second enter the chamber, calculate the current produced. Given 1 ion pair requires 35 eV. *8*

(c) (i) Describe the Quark model of hadrons, including the properties of quark. *4*

(ii) How does an up quark become a down quark ? *4*

(d) Explain the high temperature superconductivity. What are different properties of high temperature superconductors ? *8*

(e) Implement the Boolean function $X = AB + \bar{A}C$ using NAND gates. *8*

Q6. (a) Calculate the mass of deuterium nucleus if the binding energy per nucleon is 1 MeV. *10*

(b) (i) What is nuclear binding energy and how does it vary with mass number of the nucleus ? *7*

(ii) Calculate the binding energy per nucleon of ^{4}He. *8*

Given m (^{4}He) = 4·002602 u, m_p = 1·007825 u and m_n = 1·008665 u.

(c) Draw the circuit diagram of a transistor operating in the common-base configuration and sketch its input and output characteristics. Indicate the active, cut-off and saturation regions. *15*

Q7. (a) Delhi requires 3000 MWh of electric energy per day. It is to be supplied by a reactor which converts nuclear energy into electrical energy with an efficiency of 20 percent. If reactor uses nuclear fuel of U^{235}, calculate the mass of U^{235} needed for one day operation. *10*

(b) Show that the reciprocal lattice for a 'bcc' lattice is a 'fcc' structure. *10*

(c) When is the channel of a JFET said to be pinched off ? Define the pinch-off voltage. Give the relationship between the pinch-off voltage, the saturation voltage and the gate-source voltage. Sketch the depletion region before and after pinch-off. *20*

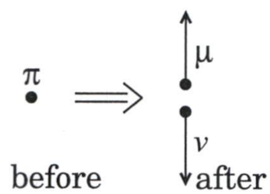
Q8. (a) Which of the following reactions are possible ? *4×3=12*

(i) $\pi^+ + n^0 \rightarrow \Lambda^0 + K^+$

(ii) $\pi^+ + n^0 \rightarrow K^0 + K^+$

(iii) $\pi^+ + n \rightarrow \pi^- + p$

(b) A pion at rest decays into a muon and a neutrino.



(i) Find the energy of the outgoing muon in terms of the two masses m_π and m_μ (assuming $m_\nu = 0$).

(ii) Find the velocity of muon. *13*

(c) When a voltage $v_1 = +\ 40\ \mu V$ is applied to the non-inverting input terminal and a voltage $v_2 = -\ 40\ \mu V$ is applied to the inverting input terminal of an Op-Amp, an output voltage $v_o = 100$ mV is obtained. But, when $v_1 = v_2 = +\ 40\ \mu V$ is applied, one obtains $v_o = 0{\cdot}4$ mV. Calculate the voltage gains for the difference and the common-mode signals, and the common-mode rejection ratio. *15*