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

SECTION A

Q1. (a) Find the condition at which de Broglie wavelength equals the Compton wavelength for a particle. *8*

(b) The time independent wave function of a system is $\psi(x) = A \exp(ikx)$, where k is a constant.

(i) Is this wave function normalizable in the domain $-\infty < x < \infty$?

(ii) Calculate the probability current density for this function. *8*

(c) The components of arbitrary vectors $\vec{A}$ and $\vec{B}$ commute with those of $\vec{\sigma}$. Show that $(\vec{\sigma} \cdot \vec{A})(\vec{\sigma} \cdot \vec{B}) = \vec{A} \cdot \vec{B} + i\vec{\sigma} \cdot (\vec{A} \times \vec{B})$. *8*

(d) An atomic state is denoted by $^4D_{5/2}$. What should be the minimum number of electrons involved for this state ? Give a possible electron configuration. *8*

(e) Often the intensity of rotational transition $J = 0 \rightarrow J = 1$ is not the most intense. Explain. *8*

Q2. (a) Evaluate the commutator $\left[\frac{\partial^2}{\partial x^2}, x\right]$ and hence show that $[p^2, x] = -2i\hbar p$. *10*

(b) For the n^{th} state of linear harmonic oscillator, evaluate the uncertainty product $(\Delta x) \cdot (\Delta p)$. *15*

(c) The raising (J_+) and lowering (J_-) operators of total angular momentum are defined by $J_+ = J_x + iJ_y$ and $J_- = J_x - iJ_y$. Find the values of the following : *15*

(i) $[J_x, J_\pm]$

(ii) $[J_y, J_\pm]$

(iii) $J_- J_+$

Q3. (a) What is vector model of the atom ? On the basis of it, explain the L-S and j-j coupling under external magnetic field. *15*

(b) How does the Stern-Gerlach experiment explain the concept of electron spin and its angular momentum quantization ? *15*

(c) Evaluate the Landé g-factor for the $^3P_1$ level in the 2p 3s configuration of the ^6C atom, and then calculate the splitting of the level in eV, when the atom is in an external magnetic field of 0·2 tesla. *10*

Q4. (a) The rotational and centrifugal distortion constants of a diatomic molecule are 10·59 cm^{-1} and 5·3 $\times$ 10^{-4} cm^{-1}, respectively. Obtain an estimate each for the vibrational frequency and force constant of the molecule. [Given : The reduced mass of the molecule is 1·626 $\times$ 10^{-27} kg] *10*

(b) Discuss the influence of anharmonicity on the vibrational spectra of diatomic molecules with necessary diagrams. *15*

(c) (i) Homonuclear diatomic molecules do not give any pure rotational or vibrational spectra, whereas they do give a rotational Raman spectra. Comment.

(ii) The separation between the adjacent rotational Raman lines is 4B in hydrogen molecule, whereas in oxygen molecule it is 8B. Why ? *7+8=15*

SECTION B

Q5. (a) The nature of curves of binding energy and packing fraction are complementary to each other. Explain. *8*

(b) Derive an expression for α-disintegration energy for a nucleus in a radioactive decay process. *8*

(c) Why can Electron-Positron pair production through a high energy photon not take place in vacuum ? *8*

(d) What will be the frequency of Josephson current, if a d.c. voltage of 4·0 μV is applied across a Josephson junction ? *8*

(e) (i) Using the logic gates, draw the circuit diagram representing the Boolean expression AB + A(B + C) + B(B + C).

(ii) Simplify the following Boolean expression :

$[AB(C + \overline{BD}) + \overline{AB}]\,CD$ *4+4=8*

Q6. (a) What do you understand by the critical size of a nuclear reactor ? Write down the common features of nuclear reactors used for the production of electricity. *20*

(b) On the basis of conservation laws, explain whether the following reactions are allowed or forbidden : *10*

(i) $\pi^- + p \longrightarrow \Sigma^+ + K^-$

(ii) $K^- + p \longrightarrow \Omega^- + K^+ + K^0$

(iii) $\Omega^- \longrightarrow \Xi^0 + \pi^-$

(iv) $\pi^+ + p \longrightarrow p + p + \bar{n}$

(v) $\Sigma^+ \longrightarrow \wedge^0 + K^+$

(c) Justify the fact that the electrons are emitted from nuclei in β-decay but they cannot be contained inside the nuclei. *10*

Q7. (a) Explain Gell-Mann and Ne'eman SU(3) symmetry for the classification of elementary particles — baryons and mesons. *10*

(b) Draw the crystal structure of CaF_2 indicating the positions of cations and anions. What are their respective coordination numbers ? *10*

(c) (i) Derive an expression for the period of Bloch oscillation for a one-dimensional crystal having lattice period a and electric field ε.

(ii) Consider an electron in a perfectly periodic lattice, wherein the energy-wavenumber relationship in the first Brillouin zone is expressed as $E = \frac{\hbar^2 k^2}{5\, m_e}$ where m_e is the mass of an electron in free space. Find the effective mass of the electron and hence write down the time-independent Schrodinger equation for the electron. Also determine the velocity of the electron. Ignore all interactions except between the electron and the lattice. *10+10=20*

Q8. (a) With the help of a schematic diagram, describe the structure of n-depletion MOSFET. Draw and describe its drain and transfer characteristics. *15*

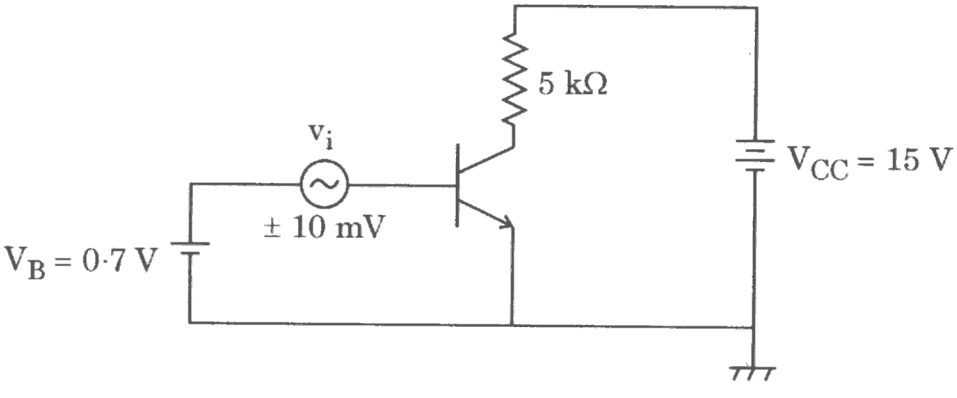
(b) Consider the BJT amplifier circuit given below with the following parameters :

d.c. current gain β_{dc} = a.c. current gain $\beta_{ac} = 100$

$I_B = 20\ \mu A$ for $V_B = 0{\cdot}7$ V, and

$i_B = \pm 2\ \mu A$ for $v_i = \pm 10$ mV.

Determine the values of V_{CE}, input impedance and voltage gain A_v. *15*



(c) Consider an n-channel JFET which has I_{DSS} = 15 mA and pinch-off voltage $V_p = -5$ V. If $V_{GS} = -1{\cdot}5$ V, how much will the drain current I_D be ? What will be the minimum value of V_{DS} for pinch-off to occur at $V_{GS} = -1{\cdot}5$ V ? *10*