Indian Forest Service
(Main) Exam, 2020

JKLO-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	$= 5{\cdot}5855\ \mu_N$	$\hbar c$	$= 197$ eVnm
m(n)	$= 1{\cdot}00866$ u	m(p)	$= 1{\cdot}00727$ u
$m({}^{12}_{6}C)$	$= 12{\cdot}00000$ u	$m({}^{4}_{2}He)$	$= 4{\cdot}002603$ u
$m({}^{2}_{1}H)$	$= 2{\cdot}014022$ u	$m({}^{87}_{38}Sr)$	$= 86{\cdot}908893$ u
$m({}^{16}_{8}O)$	$= 15{\cdot}999$ u	$m({}^{3}_{1}H)$	$= 3{\cdot}0160500$ u
$\hbar$	$= 1{\cdot}05 \times 10^{-34}$ Js	1 eV	$= 1{\cdot}60 \times 10^{-19}$ J

SECTION A

Q1. (a) (i) State and explain position momentum uncertainty principle. Justify that this principle is not just a negative statement rather a useful tool, with one example. *4*

(ii) The lifetime of an excited state of an atom is about 10^{-8} sec. Calculate the minimum uncertainty in the energy of the excited state. *4*

(b) Draw a neat sketch showing potential wells and energy levels of the following :

(i) Harmonic oscillator

(ii) Hydrogen atom

(iii) Particle in a box

List the contrasting points and mention the variation of 'E_n' with 'n' of the above plots. *8*

(c) Prove the following : *4+4=8*

(i) $[L^2, L_x] = 0$

(ii) $[L_x, L_y] = i\hbar L_3$

(d) The calcium line of wavelength $\lambda = 4226{\cdot}73$ Å (P → S) exhibits normal Zeeman splitting when placed in a uniform magnetic field of 4 Weber/metre^3. Calculate the wavelength of three components of normal Zeeman pattern and the separation between them. *8*

(e) A Raman line associated with a vibrational mode which is both Raman and infrared active is found at 4600 Å when excited by light of wavelength 4358 Å. Calculate the wavelength of the corresponding infrared band. *8*

Q2. (a) (i) What do you mean by expectation value of a physical quantity ? How does it help to extract information from a wave function ? *5*

(ii) A particle limited to move along x-axis has the wave function $\psi = ax$ between $x = 0$ and $x = 1$, $\psi = 0$ elsewhere.

Find the probability that the particle can be found between $x = 0{\cdot}45$ and $x = 0{\cdot}55$.

Find the expectation value $< x >$ of the particles position $x = 0$ to $x = 1$. *10*

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(b) Derive energies and wave functions for motion of electron in a hydrogen atom. *15*

(c) The moment of inertia of the CO molecule is $1{\cdot}46 \times 10^{-46}$ kg-m^2. Calculate the energy (in eV), and the angular velocity in the lowest rotational energy level of the CO molecule. *10*

Q3. (a) (i) Draw a neat sketch of a finite rectangular potential barrier well of height 'U' and width 'L' that contains a particle whose energy 'E' is less than 'U'. Solve the Schrödinger equations of the particles outside the well. *10*

(ii) Plot wave functions and probability densities $|\psi|^2$ of the particle for the first three states. Compare the results with that of a particle in a box of infinite potential ($U = \infty$).

(b) What is Normal Zeeman effect ? Give the classical interpretation of Normal Zeeman effect. *10*

(c) Obtain an expression for the rotational energy levels of a diatomic molecule, taking it as a rigid rotator. Discuss its spectrum and the selection rule. *15*

Q4. (a) (i) Discuss about the validity criterion for the WKB approximation.

(ii) Qualitatively explain alpha (α) particle emission by WKB approximation. *5*

(b) Explain the principle and working of Stern-Gerlach Experiment. *15*

(c) Explain the mechanism of Fluorescent emission of radiation. Distinguish between Fluorescence spectra and Raman spectra of a diatomic molecule. *15*

SECTION B

Q5. (a) Discuss in brief any two basic nuclear properties.

Find the nuclear radius of ${}^{12}_{6}C$ nucleus. Compare the atomic radius of carbon C-12 to the nuclear radius assuming the atomic radius to be $0{\cdot}529 \times 10^{-10}$ m. ($R_0 = 1{\cdot}2$ fm)

What inference will you get from the comparison with regards to nuclear size of carbon ? *8*

(b) (i) Plot proton number (Z) versus neutron number (N). What is the inference from the plot with regards to light and heavy nuclides ? *4*

(ii) Which nucleus would you expect to be more stable, ${}^{7}_{3}Li$ or ${}^{8}_{3}Li$? Justify your answer. *4*

(c) Consider atoms as hard, uniform spheres and packed closely together so that they fold touch one another. Calculate the number of atoms per cubic unit cell and fraction of volume occupied for simple cubic, body-centred and face-centred cubic structures. *8*

(d) Show that pion decay, muon decay and pair production conserve the Lepton numbers L_e and L_μ. *8*

(e) Verify the following Boolean identities : *4+4=8*

(i) $A + \bar{A} B = A + B$

(ii) $\overline{\bar{A} + B} + \overline{\bar{A} + \bar{B}} = A$

Q6. (a) (i) Write semi-empirical mass formula for the nuclei. Discuss in brief the physical significance of each term.

(ii) The meson theory of nuclear forces assumes the virtual exchange of pions. If a nucleon emits a virtual pion of rest mass 270 m_e, calculate the range of the nuclear force. (m_e is the mass of electron = $9{\cdot}11 \times 10^{-31}$ kg) *8*

(b) What is Josephson Effect ? Give an account of applications of superconductivity. *15*

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(c) A transistor operating in the CE mode draws a constant base current I_B of 30 μA. The collector current I_C is found to change from 3·5 mA to 3·7 mA when the collector-emitter voltage V_{CE} changes from 7·5 V to 12·5 V. Calculate the output resistance and β at V_{CE} = 12·5 V. What is the value of α ? *10*

Q7. (a) (i) Plot mass number A versus binding energy per nucleon. How does this curve help to explain the nuclear fission and fusion ? *10*

(ii) In their old age, heavy stars obtain part of their energy by the following nuclear reaction

$$ {}^{4}_{2}\text{He} + {}^{12}_{6}\text{C} = {}^{16}_{8}\text{O}. $$

How much energy does each such event give off ?

[Given : ${}^{4}_{2}\text{He}$ = 4·002603 u, ${}^{12}_{6}\text{C}$ = 12·000000 u, ${}^{16}_{8}\text{O}$ = 15·999 u] *5*

(b) Explain the classification of elementary particles and discuss their interactions. *10*

(c) Describe briefly the construction of an n-channel JFET. Define the pinch-off voltage and pinch-off current. Give the relationship between the pinch-off voltage, the saturation voltage and gate-source voltage. *15*

Q8. (a) A nuclear reactor using ${}^{235}_{92}\text{U}$ is to operate at a power level of 250 megawatt. If the energy released per fission of ${}^{235}_{92}\text{U}$ is 200 MeV, calculate the rate of consumption per year. *10*

(b) What is Meissner Effect ? Explain the validity of Meissner Effect in Type I and Type II superconductors. *15*

(c) Describe the basic segments of a microprocessor and briefly mention their functions. Mention the name of widely used 8-bit microprocessors. *15*