Civil Services (Main) Examination, 2001

PHYSICS
(Paper II)

Time Allowed : Three Hours **Maximum Marks : 300**

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.
Candidate has to attempt FIVE questions in all.
Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any THREE of the following:

(a) (i) Quantum theoretical methods have established themselves to explain natural phenomena in contemporary Physics. Comment. (ii) Formulate the axioms of quantum theory. (iii) State Born's condition on a wave function. What is its physical meaning? **20**

(b) (i) Find the eigenstates of the angular momentum vector component L_z [?] of a spherically symmetric system. (ii) Write down any two properties of the Pauli matrices after defining through an expression. **20**

(c) (i) State and explain Franck-Condon principle. (ii) In three separate pairs of electronic states (one ground and another upper state) of diatomic molecules, the average internuclear distances are: (1) equal, (2) slightly greater, and (3) appreciably greater. In accordance with Franck-Condon principle, obtain most favourable transitions from the ground state vibrational levels to the upper state vibrational levels in each of the three situations. Illustrate the transitions in all the aforesaid situations by drawing suitable energy level diagrams. **20**

(d) (i) What is Lamb shift? Explain it by illustrating through a suitable energy level diagram. Has Lamb shift been observed in any atom other than hydrogen? (ii) How does the 21 cm hydrogen line originate? Comment on its astronomical applications. **20**

2. (a) A particle is in a quantum system with a parabolic potential well. (i) Using appropriate method find the ground state energy. (ii) Obtain an expression for the ground state. **40**

(b) (i) Write down the matrix representation of the energy operator of a linear oscillator. (ii) A linear oscillator is prepared in the state given by

$$\psi(x)=1/\sqrt{5}\{\hat{\psi_0}(x)+\sqrt{2}\hat{\psi_1}(x)+\sqrt{2}\hat{\psi_2}(x)\}$$

Evaluate the energy of the oscillator in this state. **20**

3. (a) (i) Give briefly an account on the important historical developments to establish the concept of electron spin. (ii) Write down the eigenvalue and spin state of an electron for the spin operator $\hat{S}$. * Show that the spin states of electron are orthogonal to each other. * State the spin angular momentum commutation relations. * Give the explicit forms of all the Pauli spin matrices. **30**

(b) (i) On the basis of vector atom model, discuss briefly the L-S and J-J coupling schemes. (ii) Write down expressions for spin angular momentum, orbital angular momentum and total angular momentum under L-S coupling scheme. (iii) Obtain the energy states for ^{2}He atom for n = 1, 2, 3 levels (n is principal quantum number). Draw the energy level diagram. Does **30**

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L-S coupling scheme hold good in ^{80}Hg atom which like He has 2 optical electrons ($6S^2$)? Comment.

4. **(a)** (i) Discuss qualitatively the occurrence of rotational energy levels at a diatomic molecule. Write down the selection rule. (ii) Is it possible to obtain rotational spectra of H_2, HF, O_2, and NO molecules? Can one obtain pure rotational spectra in emission? Comment (on both of the above-mentioned querries). (iii) In CO molecule J = 0 → J = 1 line occurs at frequency 1.153×10^{11} Hz. Calculate the moment of inertia of CO molecule. **30**

(b) (i) What is Raman effect? How does it differ from Rayleigh scattering? Write down its important applications. (ii) Explain Raman effect with the aid of quantum mechanical theory. (iii) Why is Raman effect considered complimentary to infrared absorption spectra? (iv) A Raman Stokes' line is observed at 552 nm when a sample is excited by Hg green line of wavelength 546 nm. Calculate the wavelength of anti-Stokes' line. **30**

SECTION 'B'

5. Answer any THREE of the following:

(a) Use conservation laws to find the nature of residual nucleus when 50.0 MeV proton beam strikes the beryllium ($_4^9Be$) target nucleus producing a beam of neutrons. **20**

(b) Illustrate with any five examples that production of strange particles conserves strangeness, parity and isotopic spin while their decay violates all these quantities. **20**

(c) (i) Obtain reciprocal lattice to normal BCC lattice. (ii) Describe Josephson junction and the effect. How is it exploited in the formation of a SQUID? Write down the applications of a SQUID. (iii) Distinguish between intrinsic and extrinsic semiconductors. Explain the concept of hole. **20**

(d) (i) FETs have unique properties which make BJTs not suitable for some important applications. What are these most important FET applications? (ii) Briefly describe FETs as variable resistors. **20**

6. **(a)** Discuss briefly the concepts of fission barrier, excitation energy and activation energy on the basis of liquid drop model. Why $_{92}^{235}U$ is fissionable by thermal neutrons while $_{92}^{238}U$ is not? **15**

(b) Classify the Indian power reactors into BWR, PHWR and FBR varieties, explaining the acronyms, type of fuel used and location for each variety. **10**

(c) A nuclear reactor operates at a power level of 10^8 W. What will be the flux of neutrons required to maintain this power level? Given that a free neutron has an average lifetime of 10^{-3} second before its capture in a uranium nucleus and energy released per fission is 200 MeV. **15**

(d) Describe briefly the various cycles for energy production in stars, relating them to the life history of a star. "Fusion reactors operate in the core of stars but have not become a reality on earth as yet." Comment on the statement. **20**

7. **(a)** Discuss the significance of Gellmann-Nishijima relation in strange particle production and decay. Give examples in support of your answer. Obtain quark quantum numbers using the modified relation for quarks. **15**

(b) Describe important experimental facts that led Pauli to postulate the existence of neutrino particle. **15**

(c) (i) Give a qualitative account of BCS theory of superconductivity. (ii) Obtain an expression for conductivity of an intrinsic semiconductor. How does it vary with temperature? (iii) The resistivity of an intrinsic semiconductor is 4.5 ohm-m at 20°C and 2.0 ohm-m at 32°C. Calculate the energy band gap. **30**

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8. **(a)** Combinational switching circuit can perform an addition of the numbers held in two registers. (i) Write down the math table for the addition of two bits. (ii) Write down a Boolean expression for the necessary circuit functions. (iii) Arrive at the Exclusive-OR function. (iv) Draw the logic diagram for the circuit which performs the addition. **10**

(b) (i) What are sequential switching circuits (ii) Describe a simple sequential circuit. (iii) Describe a clocked RS Flip-Flop, (iv) Briefly describe ROMs. **40**

(c) Explain a solar cell employing its characteristics on output quantity versus quantities like load current, radiance and temperature. **10**

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