

Time Allowed : Three hours

Maximum Marks : 300

The figures in the margin indicate full marks for the questions

Candidates should answer Question Nos. **1** and **5** which are compulsory and *any three* of the remaining questions, selecting at least **one** from each Section

Assume suitable data if considered necessary and indicate the same clearly

SECTION—A

1. Answer any *three* of the following : 20×3=60
- (a) For a particle in a one-dimensional box, (i) discuss the zero-point energy, (ii) show that the wave functions for two different states are orthonormal, and (iii) obtain the expectation values for x and p_x . 5+5+10=20
- (b) Apply the Schrödinger equation to the 3-D problem of the hydrogen atom to obtain the equation representing the uniform motion of the centre of mass, and the relative motion. 20
- (c) In which regions of the electromagnetic spectrum do you expect to get (i) rotational, (ii) vibrational and (iii) electronic spectra? Why are electronic spectra given by all molecules? State Franck-Condon principle and explain the intensity distribution in electronic spectra with the help of this principle. Give the wave-mechanical formulation of the Franck-Condon principle. 3+2+10+5=20
- (d) Obtain the expressions for the wave numbers of the three components (to which the original line splitted up) in the normal Zeeman effect. Show the magnetic splitting of a spectral line originating from the transition between the two levels with $l=2$ and $l=1$ with a diagram. Explain the origin of the anomalous Zeeman effect and obtain the expression for the Lande g -factor. Show, in a diagram, the anomalous Zeeman effect for sodium D_1 and D_2 lines. 5+3+3+6+3=20
2. (a) What does quantum tunnelling refer to? Where does this phenomenon find applications? How is the WKB formula used for the lifetime calculation in alpha decay? 2+2+16=20

- (b) Find the eigenfunctions when a particle is kept in a rectangular box of dimensions $l_x \times l_y \times l_z$. Find the eigenvalues of momentum and energy. Explain the term degeneracy. 7+6+7=20
- (c) Define Pauli spin matrices. How is the behaviour of the electron spin treated by Pauli's theory? What are spinors? Write a general state, and normalise it. Discuss the commutation relation between the spin operators. What is a Riemann sphere? 3+9+2+3+3=20
3. (a) Which experiment gave a direct experimental proof of the existence of the magnetic moment associated with the spin of the electron? Describe that experiment in detail. What other proof was provided by that experiment? 1+17+2=20
- (b) Explain why the state of largest L is of lowest energy. What is the requirement for an atom in which (i) L - S coupling and (ii) j - j coupling hold?
- Consider an atom having two optical electrons with outer configuration $4p\ 4d$. Considering (i) L - S coupling, obtain all the terms, (ii) j - j coupling, find the possible values of J . 3+3+7+7=20
- (c) How does the spin-orbit interaction, when combined with the relativity correction, explain the hydrogen fine structure? Discuss its limitations. 16+4=20
4. (a) What is the argument for considering a diatomic molecule as an anharmonic oscillator? Write the Morse function and the pattern of the allowed vibrational energy levels when this function is inserted in the Schrödinger equation. Sketch the vibrational energy levels. Show that the zero-point energy differs slightly from that of the harmonic oscillator. Write expressions for $\Delta\varepsilon$ (in cm^{-1}) for the transitions $\nu = 0 \rightarrow \nu = 1$ ($\Delta\nu = +1$), $\nu = 0 \rightarrow \nu = 2$ ($\Delta\nu = +2$) and $\nu = 0 \rightarrow \nu = 3$ ($\Delta\nu = +3$). What are hot bands?
- The following lines are observed in the absorption spectrum of HCl :
- $2886\ \text{cm}^{-1}$ (very intense), $5668\ \text{cm}^{-1}$ (weak), $8347\ \text{cm}^{-1}$ (very weak).
- Calculate the equilibrium oscillation frequency and anharmonicity constant of the anharmonic system. 2+4+2+4+6+2+5=25
- (b) What type of scattering does the Raman effect represent? Why is Stokes' radiation usually more intense than anti-Stokes' radiation? Explain the classical theory of Raman effect. Explain the statement—"Symmetric vibrations give rise to intense Raman lines; non-symmetric ones are usually weak and sometimes unobservable". 2+2+8+8=20

- (c) Define luminescence. Explain fluorescence and phosphorescence with a suitable diagram. What is the approximate order of fluorescence and phosphorescence lifetimes? Differentiate between fluorescence and Raman spectra. Mention a few applications of fluorescence. 2+6+2+3+2=15

SECTION—B

5. Answer any *three* of the following : 20×3=60

(a) Briefly explain the nature of nuclear forces. What role do pions play in nuclear forces? 10+10=20

(b) What are elementary particles? Discuss the method of their classification and their chief characteristics. 2+18=20

(c) What is Meissner effect? How does this effect contradict Maxwell's equations? Explain the persistent currents set up inside the superconductors according to this effect. Define penetration depth. Write notes on Type I and Type II superconductors. 2+2+8+8=20

(d) State De Morgan's theorem and draw the equivalent logic circuits. De Morganise the functions (i) $\overline{A \cdot B}$ and (ii) $\overline{A \overline{B}} + C$.

Simplify the given Boolean expression and realise an equivalent circuit using basic gates :

$$Y = \overline{A \overline{B} C} + \overline{A \overline{B} \overline{C}} + \overline{A B \overline{C}} + \overline{A \overline{B} C} \quad 6+6+8=20$$

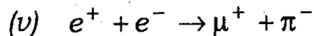
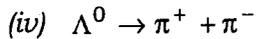
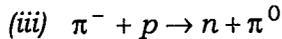
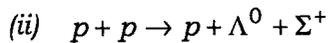
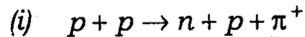
6. (a) Discuss properties of the nucleus regarding its charge, mass, radius, binding energy, spin, magnetic moment, statistics, parity and electric moment. How is the concept of binding energy related to the stability of the atomic nucleus? 9+11=20

(b) Write a note on the evidence for the shell structure of the nuclei. Discuss the shell model of the nucleus, mentioning its achievements and failures. 8+12=20

(c) Discuss the neutrino theory of β -decay, explaining the continuous energy spectrum in β -decay. Discuss, giving examples, different types of β -emission along with the conditions in which these take place. 10+10=20

7. (a) Mention the intrinsic quantum numbers associated with the elementary particles, giving their corresponding conservation laws.

Conclude on the occurrence of the following reactions :



10+10=20

- (b) State the types of lattices, angles between the axes and relation between the length of primitives for the seven classes of crystals. Explain the three types of cubic crystals in detail.

11+9=20

- (c) Describe the model of one-dimensional periodic potential as treated by Kronig and Penney, and plot a curve showing the energy E as a function of k . How does the band theory lead to a possibility of a distinction between metals, semiconductors and insulators?

16+4=20

8. (a) What are class A and class B types of amplifiers? Mention the merits of negative feedback in amplifiers. Draw the circuit diagram of a two-stage $R-C$ coupled amplifier consisting of two single-stage transistor amplifiers using the CE configuration. Draw its equivalent circuits in (i) low-frequency, (ii) mid-frequency and (iii) high-frequency ranges. Draw the frequency response of this amplifier.

4+2+3+9+2=20

- (b) What are the characteristics of an ideal OP-AMP? What are summing point and virtual ground? Describe how you will use it as (i) adder, (ii) subtractor, (iii) integrator and (iv) differentiator. Describe its use in analog computation.

2+3+8+7=20

- (c) Draw the physical structure of a JFET and explain the basic operation. Write short notes on enhancement and depletion MOSFETs.

10+10=20
