

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. (a) Calculate the wavelength of de Broglie waves associated with electrons accelerated through a potential difference of 200 V. 10
- (b) Normalize the wave function $\psi(x) = e^{-|x|} \sin \alpha x$ 10
- (c) Let σ be the vector operator with components equal to the Pauli spin matrices σ_x , σ_y and σ_z . If $\mathbf{a}$ and $\mathbf{b}$ are the vectors in 3-dimensional space, prove the identity $(\sigma \cdot \mathbf{a})(\sigma \cdot \mathbf{b}) = \mathbf{a} \cdot \mathbf{b} + i\sigma \cdot (\mathbf{a} \times \mathbf{b})$ 10
- (d) Discuss the fine structure of hydrogen atom spectrum. Draw the compound doublet spectrum arising as a result of transitions between ^2P and ^2D levels. 10
- (e) What do you mean by 'term symbols'? Obtain term symbols for the following sets of values of S and L: (i) $S=1/2, L=2$ (ii) $S=1, L=1$ (iii) $S=3/2, L=1$ 10
- (f) Estimate the size of the hydrogen atom and the ground-state energy from the uncertainty principle. 10
2. (a) Solve the Schrödinger equation for a particle of mass m in an infinite rectangular well defined by the potential $[V(x) = 0, 0 \leq x \leq L; = \infty, x < 0, x > L]$ 25
Obtain the normalized eigenfunctions and the corresponding eigenvalues. 15
- (b) Calculate $(\Delta x)^2$, where $\Delta x = x - \langle x \rangle$. 15
- (c) The normalized wave function for the electron in the ground state of the hydrogen atom is given by $\psi(r) = 1/(\pi a_0^3)^{1/2} e^{(-r/a_0)}$ 20
where a_0 is the radius of the first Bohr orbit. Calculate $\langle r \rangle$ and $\langle 1/r \rangle$. 20
3. (a) Show that $^2S_{1/2}$, $^2P_{1/2}$ and $^2P_{3/2}$ levels of sodium spectrum are split in the ratio of 3:1:2 due to anomalous Zeeman effect. 30
- (b) On the basis of three principal moments of inertia I_A , I_B and I_C each about X, Y and Z axes respectively, how can you classify molecules? 30
4. (a)(i) Treating a diatomic molecule as a simple harmonic oscillator, obtain its vibrational energy levels. 20
- (a)(ii) The observed vibrational frequency of the CO molecule is 6.42×10^{13} Hz. What is the effective force constant of this molecule? (Mass of carbon atom = 12 u and mass of 10

oxygen atom = 16 u, where u is atomic mass unit)

- (b)(i) Discuss pure rotational spectra of linear molecules. 25
- (b)(ii) What is Lamb shift? 5

SECTION 'B'

5. (a) Show that nucleus is a quantum system. 10
- (b) Derive Bragg diffraction condition in vectorial form using incident and diffracted wave vectors and reciprocal lattice vector. 10
- (c) Find the total kinetic energy of electron and antielectron neutrino emitted in beta decay of free neutron. (The neutron-proton mass difference is 1.30 MeV and mass of electron is 0.51 MeV) 10
- (d) An electron beam of 4 keV is diffracted through a Bragg angle of 16° for the first maxima. If the energy is increased to 16 keV, find the corresponding Bragg angle for diffraction. 10
- (e) Explain conservation of baryon number. Comment on stability of proton. 10
- (f) Simplify the logical expression

$$AB + \bar{A}\bar{B} + ABC$$
using a Karnaugh map. 10
6. (a)(i) What is the importance of study of deuteron? Obtain the solution of Schrödinger equation for ground state of deuteron and show that deuteron is a loosely bound system. 25
- (a)(ii) What do you mean by 'non-central forces'? 5
- (b)(i) What are chain reactions? What do you mean by critical size of the core in which chain reaction takes place? What is critical mass? 20
- (b)(ii) ^{235}U yields two fragments of $A=95$ and $A=140$. Obtain the energy distribution of the fission products. Assume that the two fragments are ejected with equal and opposite momentum. 10
7. (a) Find an expression for lattice specific heat of solids, and its low and high temperature limits. What is Debye temperature? 20
- (b) Explain the origin of energy band formation in solids. Show that in nearly free electron approximation, the energy band gap is $2|V_G|$, where V_G is Fourier transform of periodic potential seen by the valence electrons. 20
- (c) Describe the characteristic properties of a superconductor. Derive London equation for a superconductor and hence explain Meissner effect. 20
8. (a) Distinguish between intrinsic and extrinsic semiconductors. Show that in a semiconductor, the product of concentrations of the two types of charge carriers is constant at a given temperature. 30
- (b) Simplify the logical expression

$$\overline{((A+B))} B (A+\bar{C})$$
and draw the logical circuit to implement it. 15
- (c) Draw the common-base amplifier circuit, using an n-p-n transistor and briefly discuss its working. 15