

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) Use the uncertainty principle to estimate the ground state energy of a linear harmonic oscillator. 12
- (b) Given that $\sigma_x, \sigma_y, \sigma_z$ are Pauli spin operators, prove the following relationships:
- (b)(i) $\sin(\sigma_x \varphi) = \sigma_x \sin \varphi$ 6
- (b)(ii) $\cos(\sigma_z \varphi) = \cos \varphi$ 6
- (c) Consider the one dimensional wavefunction $\psi(x) = A x e^{-kx}$, ($0 \leq x < \infty$; $k > 0$)
- (c)(i) Calculate A so that $\psi(x)$ is normalized. 4
- (c)(ii) Using Schrödinger's equation find the potential $V(x)$ and energy E for which $\psi(x)$ is an eigenfunction. (Assume that as $x \rightarrow \infty$, $V(x) \rightarrow 0$). 8
- (d) Sodium doublets are produced by transitions $3^2p_{1/2} \rightarrow 3^2s_{1/2}$ (D_1) and $3^2p_{3/2} \rightarrow 3^2s_{1/2}$ (D_2). Calculate the Landé g-factors for these levels. 12
- (e) Why should rotational Raman spectrum show a separation of the first Raman line from the exciting line equal to $6B \text{ cm}^{-1}$, while the separation between successive lines equals to $4B \text{ cm}^{-1}$, where B is the rotational constant? 12
2. (a) Solve the radial part of the time-independent Schrödinger equation for a hydrogen atom. Obtain an expression for the energy eigenvalues. 45
- (b) What is the degree of degeneracy of the energy eigenvalues? What happens if the spin of the electron is taken into account? 15
3. (a) When a nucleus with spin 3/2 is subjected to magnetic field, how does the energy level split and what will be the energy of separation between any two adjacent levels? 20
- (b) Estimate the spin-lattice relaxation time in terms of transition probability for a nucleus with spin $I=1/2$. 20
- (c) Why should proton chemical shift in CH_3CHO occur when it is subjected to a magnetic field? 20
4. (a) What will happen to the energy level of an unpaired electron when subjected to an external magnetic field? Find the condition for electron spin resonance. 20
- (b) Describe the vibration-rotation spectra of a polyatomic linear molecule. What are P, Q and R branches? Draw rotational energy levels of the vibrational states $v=0$ and $v=1$ and perpendicular vibrational-rotational transitions of a linear polyatomic molecule. 40

SECTION 'B'

5. (a) Determine from the given data whether the following reactions are exothermic or endothermic: (i) ${}^1_1\text{H} + {}^3_1\text{H} \rightarrow {}^2_1\text{H} + {}^2_1\text{H}$ (ii) ${}^{12}_6\text{C} + {}^{12}_6\text{C} \rightarrow {}^{20}_{10}\text{Ne} + {}^4_2\text{He}$ 12
- (b) Calculate the recoil energy of ${}^{57}_{26}\text{Fe}$ nucleus when it emits a gamma photon of energy 14 keV. 12
- (c) Which of the following reactions are permitted or forbidden by various conservation laws? (i) $k^- + p \rightarrow \Lambda + \pi$ (ii) $k^+ + n \rightarrow \Sigma^+ + \pi$ (iii) $\pi^- + p \rightarrow k^- + \Sigma^+$ (iv) $\pi^+ + n \rightarrow k^+ + \Lambda$ (v) $\pi^- + p \rightarrow \Lambda + k$ (vi) $\pi^- + p \rightarrow k^+ + \Sigma^-$ 12
- (d) Metallic iron undergoes a structural phase transition from bcc to fcc at 910°C. At this temperature, the atomic radii of iron atoms in the bcc and fcc structures are 0.126×10^{-9} m and 0.129×10^{-9} m respectively. Calculate the volume change in percentage during this structural change. 12
- (e) What are the rules followed in biasing a bipolar junction transistor when it is used as an amplifier? Show how n-p-n and p-n-p transistors to be used as an amplifier are biased and the direction of flow of base, collector and emitter currents. 12
6. (a) Write down the Bethe-Weizsäcker semiempirical mass formula for a nucleus. Explain the significance of each term occurring in it. Discuss the stability of a nucleus against β -decay. What is the effect of pairing term on stability? 45
- (b) What are mirror nuclei? How does the charge independence of nuclear force emerge from this concept? 15
7. (a) Starting from an expression for the group velocity, arrive at an expression for the effective mass of an electron in a semiconductor. Explain the significance of sign of the effective mass. 30
- (b)(i) Classify diamagnetic, paramagnetic and ferromagnetic materials in terms of their magnetic susceptibility (χ). Plot and explain the variation of $1/\chi$ with temperature for the three materials. 15
- (b)(ii) Explain the variation of magnetisation of a type-I and type-II superconductors as a function of applied magnetic field. 15
8. (a) Construct an operational amplifier based analog computer to solve the differential equation
$$d^2v/dt^2 - dv/dt + 2v = 0.$$
 30
- (b) Explain the race problem encountered in an RS latch and how it can be avoided. Build a Mod-10 counter using JK flip-flops and explain its working. 30