

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:

20×3=60

(a)(i) Write the commutation relations for the position variable x and the momentum components p_x , p_y , and p_z . Explain the physical significance of these relations.

(a)(ii) Calculate the de Broglie wavelength of an electron moving with a kinetic energy of 1 MeV.

(b)(i) How many lines occur in the multiplet arising from $^2P_{3/2} \rightarrow ^2S_{1/2}$ and $^2P_{1/2} \rightarrow ^2S_{1/2}$ transitions of alkali metal atoms placed in a weak magnetic field, why?

(b)(ii) The wavefunction of a particle confined in a cube of volume L^3 is given by

$$\Psi(x,y,z) = (2/L)^{3/2} \sin \pi x/L \sin \pi y/L \sin \pi z/L$$

Calculate the average values of p_x and p_x^2 in the region $0 < x < L$.

(c)(i) Explain the molecular phenomenon of spontaneous emission between two electronic states of the same multiplicity and differentiate it from that of different multiplicity.

(c)(ii) The constants B and V_0 for a KCl molecule have values 1.43×10^{-5} eV and 8.4×10^{12} s⁻¹ respectively. Determine the number of rotational levels between the vibrational levels $v=0$ and $v=1$.

(d)(i) The ground state wavefunction of a linear simple harmonic oscillator is

$$\psi = A \exp(-\alpha^2 x^2/2)$$

Calculate the constant A and the average values of x^2 and x . Given that

$$\int_0^\infty e^{-x^2} dx = (\pi^{1/2})/2$$

(d)(ii) How can the pure rotation spectrum of H_2 molecule be observed? If the bond length of H_2 molecule is 0.07417 nm, what would be the spacing of lines in its spectrum?

2. (a) Consider a particle of mass m in an infinite one dimensional potential well of width a . The particle is found in the state given by

$$\psi(x) = c[\sin \pi x/a + 1/2 \sin 2\pi x/a]$$

(i) Calculate c . (ii) If a measurement of energy is made, what are the possible results and what are the probabilities for each one of them?

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(b) Discuss WKB approximation and apply the same to determine the transition probability for leakage through a potential barrier.

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3. (a) Set up the time-independent Schrodinger equation for an electron moving in Coulomb field, $V(r)=Ze^3/4\pi\epsilon_0 r$, in polar coordinates. Solve the radial equation to get the energy eigen values. **40**
- (b) Describe Stern-Gerlach experiment and discuss its implications. **20**
4. (a) Differentiates between Rayleigh and Raman scatterings. Why is Raman scattering considered to be a breakthrough in molecular spectroscopy? What are the advantages of using laser light in Raman spectroscopy? **30**
- (b) Obtain an expression for the vibration-rotation energy levels of a diatomic molecule in a given electronic state. The wave numbers of the vibrational transitions occurring in HF, HCl and HI molecules are 4141.3 cm^{-1} , 2988.9 cm^{-1} and 2309.5 cm^{-1} respectively. Compare the force constants of these three molecules. **30**

SECTION 'B'

5. Answer any three of the following:
- (a)(i) Write the Weizacker mass formula and explain the significance of various terms. **15**
- (a)(ii) Determine the amount of $^{210}_{84}\text{Po}$ necessary to provide a source of α -particles of strength 5 mCi . The half-life of $^{210}_{84}\text{Po}$ is 138 d. **5**
- (b)(i) State the quantum numbers I_z , Y and S for the uds quarks and antiquarks. What combination of these leads to the formation of (a) proton and (b) neutron? **6**
- (b)(ii) An In As semiconductor sample is cut in the form of a small bar of size $1.0\text{ cm} \times 1.0\text{ cm} \times 2.0\text{ mm}$. Its lengthwise resistance is $1.25\ \Omega$. A Hall field of 1.7 V/m develops when a current of 0.12 A is passed lengthwise and a magnetic field of 0.05 T is applied normal to its length as shown above. Calculate the carrier density.
[Figure: Printed above the text of (ii): a rectangular bar (cuboid) drawn in perspective, with hidden edges dashed; an arrow labelled I points horizontally to the right along the length of the bar (current lengthwise), and an arrow labelled H points vertically upward from the top face (magnetic field normal to the length).] **6**
- (b)(iii) Determines the reciprocal lattice vectors of an fcc lattice. **8**
- (c)(i) Draw the logic circuit for the following Boolean expression: $Y = \overline{(A+B)} + \overline{C}$ What are the 'Y' values for the input combinations: (1) 1, 1, 0; (2) 1, 0, 1; (3) 0, 0, 1? **12**
- (c)(ii) Define α and β parameters of a transistor. A germanium transistor with $\beta=45$ is biased as shown above. Calculate the value of R_b .
[Figure: Printed above the text of (ii): collector-feedback bias circuit of an npn transistor (emitter arrow pointing outward). Supply $V_{CC}=24\text{ V}$ at the top connects through a $10\text{ K}\Omega$ collector resistor to the collector. The base resistor R_b is connected between the collector node (below the $10\text{ K}\Omega$ resistor) and the base. The emitter goes through a $300\ \Omega$ resistor to ground. A dimension arrow between two dashed horizontal lines drawn level with the collector node and the emitter node is marked 5 V (i.e. collector-emitter voltage 5 V).] **8**
- (d)(i) Discuss briefly the concept of effective mass in semiconductors and explain the significance of negative effective mass. **10**
- (d)(ii) In isolated atoms, the electrons have discrete and definite energies but in solids they have bands of energies. Explain why. **5**
- (d)(iii) A proton, deuteron and α -particle accelerated through the same potential difference, on entering a region of uniform magnetic field applied normal to their plane of motion, move in circular orbits. Compare the radii of the orbits described by them. **5**
6. (a) Describe how parity violation was experimentally detected in ^{60}Co β -decay. How was the observed asymmetry in the distribution of emitted electrons explained? **30**
- (b) (i) Differentiate between K-capture and inverse β -decay. (ii) Explain what is internal conversion and how it differs from β -decay. **20**
- (c) Calculate the spin and parities of the ground states of ^4_2He and $^{67}_{30}\text{Zn}$ nuclei. **10**

7. (a) (i) What are the basic interactions in nature? Give one example for each. Compare their relative strengths and ranges. (ii) What are the conservation laws for strong, electromagnetic and weak interactions? (iii) Distinguish between particle and anti-particle. How was positron discovered? 30
- (b) Discuss the motion of an electron in one-dimensional periodic potential and show that it leads to formation of bands of allowed and forbidden states in the electron energy spectrum. How are the insulators, semi-conductors and conductors discriminated on the basis of band structure? 30
8. (a) Define (i) input bias current, (ii) input offset current, (iii) input offset voltage, (iv) output offset voltage, (v) power supply rejection ratio and (vi) slew rate for an OPAMP. 30
- (b) Discuss the functioning of the above oscillator circuit. Obtain the condition for maintenance of oscillations and the expression for the frequency assuming that the resistances of the inductors are negligible.
- [Figure: Printed before the text of (b): transistor Hartley oscillator (npn transistor). V_{cc} at the top feeds two branches: through resistor R_1 down to the base node, and through an RFC (radio-frequency choke) down to the collector. Resistor R_2 runs from the base node down to the bottom of the emitter network. The emitter goes through R_e shunted by capacitor C_e to a node that is connected to ground. The tank circuit at the bottom: two inductors L_1 (left) and L_2 (right) in series with their common junction grounded; a variable capacitor C is connected across the outer ends of L_1 and L_2 . The base is coupled through capacitor C_b to the outer (left) end of L_1 , and the collector is coupled through capacitor C_c to the outer (right) end of L_2 .]
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