

PHYSICS

(Paper II)

Time Allowed : Three Hours
Maximum Marks : 250

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.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

SECTION 'A'

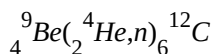
1. (a) In a series of experiments on the determination of the mass of a certain elementary particle, the results showed a variation of $\pm 20 m_e$, where m_e is the electron mass. Estimate the lifetime of the particle. 10
- (b) Using the definition $\mathbf{L} = \mathbf{r} \times \mathbf{p}$ of the orbital angular momentum operator, evaluate $[L_x, L_y]$. 10
- (c) The normalized wave function for the electron in the ground state of the hydrogen atom is given by $\psi(r) = 1/\sqrt{\pi a_0^3} e^{-r/a_0}$, where a_0 is the radius of the first Bohr orbit. Calculate the probability of finding the electron within a distance r_0 of the proton in the ground state. 10
- (d) How are electrons distributed in the various sub-shells for $n=3$? Give the quantum numbers for the electrons in the second shell. 10
- (e) What do you understand by H-one (HI) interstellar clouds and their importance to understand the universe. 10
2. (a) [Figure: One-dimensional step potential: graph of $V(x)$ against x ; $V=0$ for $x<0$ and $V=V_0$ (constant) for $x>0$, the step rising at the origin, labelled 0; vertical axis labelled $V(x)$, horizontal axis x .]
Consider a beam of particles incident on a one-dimensional step function potential with energy $E > V_0$ as shown in the above figure. Solve the Schrödinger equation and obtain expressions for the reflection and transmission coefficients. 30
- (b) What are the limits of the reflection coefficient for $E \rightarrow V_0$ and $E \rightarrow \infty$? 10
- (c) Discuss the cases $0 < E < V_0$ and $E < 0$. 10
3. (a) With proper selection rules, construct the energy level diagram and allowed transitions for ESR spectrum of hydrogen atom. 30
- (b) Why are Raman active vibrations and infrared vibrations in CO_2 molecule complementary to each other? 10
- (c) In a Raman spectrum of a linear triatomic molecule, the first three lines are 4.86, 8.14 and 11.36 cm^{-1} . Calculate the rotational constant, B and the moment of inertia of the molecule. (Given $h = 6.626 \times 10^{-27} \text{ J.s}$, $C = 3.0 \times 10^{10} \text{ cm/sec}$.) 10
4. (a) The term symbol for atomic states are quoted as $^3P_2$ and $^2D_{5/2}$. What are the values of L , S and J ? 10
- (b) Discuss the fine structure of sodium D line. Draw D_1 and D_2 lines due to the transitions between ^2P and ^2S levels. 25

- (c) Show that the velocity of electron in the first orbit of hydrogen atom is $(1/137)C$ where C is the velocity of light. (Given electronic charge $=1.602 \times 10^{-19}$ C Planck Constant 6.63×10^{-34} J.s, permittivity $=8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$)

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SECTION 'B'

5. (a) Calculate the Q-value of the reaction:



Given: Mass $({}_4^9\text{Be})=9.01283 \text{ u}$, Mass $({}_2^4\text{He})=4.002603 \text{ u}$, Mass $({}_6^{12}\text{C})=12.000 \text{ u}$, Mass $(n)=1.0086652 \text{ u}$

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- (b) Write down the nucleonic configuration of, ${}^7\text{Li}$, ${}^{12}\text{C}$, ${}^{17}\text{O}$ and ${}^{27}\text{Al}$ in the ground state of the nuclear shell model and hence calculate the corresponding ground state angular momenta and parities. How do the observed ground state angular momenta and parities agree with those predicted on the basis of shell model?

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- (c) State the quantum numbers I_z , Y and S for the u d s quarks and antiquarks. Which combination of these leads to the formation of (i) proton and (ii) neutron?

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- (d) [Figure: A crystal plane drawn on three mutually perpendicular axes x , y , z meeting at the origin (x towards the lower left, y towards the lower right, z vertically up). Unit lengths a , b and c are marked by dots on the x , y and z axes respectively. The plane is the triangle joining its intercepts: $1a$ on the x -axis, $3/2 b$ on the y -axis and $2c$ on the z -axis.]

A crystal plane is shown in the above figure. Find its Miller indices and interplanar spacing.

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- (e) Draw and explain the collector characteristics of a bipolar junction transistor in common emitter configuration. Using the plot, explain how the transistor can be used as an ON-OFF switch.

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6. (a) Explain parity violation in β -decay. Describe how parity violation was experimentally detected in the decay of ${}^{60}\text{Co}$. Mention any other decay process in which the parity violation has been demonstrated.

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- (b) What is the role of neutrino in the weak interaction of radioactive nuclides? Explain the experimental detection of neutrino.

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- (c) In the following reactions indicate with an explanation, whether they proceed by strong, electromagnetic or weak interaction or they are forbidden: (i) $\pi^+ \rightarrow \mu^+ + \nu_\mu$ (ii) $p \rightarrow n + e^+ + \nu_e$ (iii) $p + \pi^- \rightarrow K^+ + \Sigma^-$

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7. (a) Starting with the expression for the density of states for electrons in a band, show that the Fermi energy of an intrinsic semiconductor is at the middle of the band gap. Use these results to estimate the electron density at 300 K (Assuming $E_g = 1 \text{ eV}$ and the rest masses of electron and hole as m_e and m_h).

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- (b) A perfect conductor and a superconductor with $T_c \sim 10 \text{ K}$ are subjected to the following conditions: (i) cooled under applied magnetic field to 4 K (ii) cooled to 4 K and then magnetic field is applied with schematic diagrams, explain path of magnetic field lines in all these situations.

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- (c) Show that the London equation $\nabla \times \mathbf{J} = -1/\mu_0 \lambda_L^2 \mathbf{B}$ or $\mathbf{j} = -C/4\pi \lambda_L^2 \mathbf{A}$ leads to the Meissner effect.

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8. (a) [Figure: Tank circuit: two capacitors $C_1 = 70 \text{ pf}$ and $C_2 = 20 \text{ pf}$ connected in series in the left vertical branch, in parallel with an inductor $L = 20 \mu\text{H}$ in the right vertical branch; output terminals taken from the middle of the top wire and the middle of the bottom wire (the junction between C_1 and C_2 is not brought out).]

Explain how the circuit shown above can be a source of oscillations. Use this circuit to construct a transistor oscillator and explain its working. What is the frequency of oscillations of this circuit?

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- (b) Construct a digital circuit to add three bits A , B and C and provide their sum and carry as outputs. Show appropriate Boolean expressions and truth table to justify the outputs.

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