

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) Derive Bohr's angular momentum quantization condition in Bohr's atomic model from the concept of de Broglie waves. 10
- (b) Obtain an expression for the probability current for the plane wave $\psi(x,t)=\exp[i(kx-\omega t)]$. Interpret your result. 10
- (c) Show that the Pauli spin matrices satisfy the following:

$$\sigma_x^2 = \sigma_y^2 = \sigma_z^2 = 1$$

$$\sigma_x \sigma_y = -\sigma_y \sigma_x = i\sigma_z$$

$$\sigma_y \sigma_z = -\sigma_z \sigma_y = i\sigma_x$$

$$\sigma_z \sigma_x = -\sigma_x \sigma_z = i\sigma_y$$
10
- (d) Calculate, giving necessary steps, the radio frequency at which nuclear magnetic resonance occurs in water kept in a uniform magnetic field of 2.4 T. The magnetic moment of proton is $2.793 \mu_N$. 10
- (e) State and explain Franck-Condon principle. Discuss its applications in molecular spectroscopy. 10
- (f) The normalized wave function for the electron in hydrogen atom for the ground state is

$$\psi(r) = (\pi a_0^3)^{-1/2} \exp(-r/a_0)$$
 where a_0 is the radius of the first Bohr orbit. Show that the most probable position of the electron is a_0 . 10
2. (a) A system is described by the Hamiltonian operator,

$$H = -d^2/dx^2 + x^2$$
 show that the function $Ax \exp(-x^2/2)$ is an eigen function of H. Determine the eigen values of H. 30
- (b) A stream of particles of mass M and energy E is directed from left to a one dimensional potential barrier as shown in the above figure. Set up the time-independent Schrödinger equation and obtain an expression for transmission probability from region I to II. How this phenomenon helps in the understanding of α -decay of nuclei? 30

[Figure (printed above the text of part (b)): One-dimensional rectangular potential barrier along the x-axis (arrow pointing right, labelled x). The potential is zero for $x < 0$ (region I, on the left) and for $x > a$ (region II, on the right); between $x = 0$ and $x = a$ there is a rectangular barrier of height V_0 (a double-headed vertical arrow inside the barrier marks V_0). In region I a horizontal arrow pointing right towards the barrier is labelled E (incident particles of energy E). The left edge of the barrier is at 0 and the right edge at a.]

3. (a) What is Zeeman effect? How it can be understood on quantum mechanical basis? Obtain an expression for Zeeman splitting of atomic energy levels in a magnetic field B. Explain the magnetic splitting of sodium D-lines. **30**
- (b) What is spin-orbit interaction? Calculate the energy shift due to spin-orbit interaction term in H-like system. Discuss the significance of this shift in relation to the fine structure of hydrogen spectral lines. **30**
4. (a)(i) Discuss occurrence of rotational energy levels of a diatomic molecule and show that the pure rotation spectrum of such a molecule consists of a series of equally spaced lines separated by a constant wave number difference $2B$. Write down the selection rules. **15**
- (a)(ii) Is it possible to obtain pure rotational spectra of H_2 , HF, O_2 and NO molecules? **5**
- (a)(iii) In CO molecule $J=0 \rightarrow J=1$ line occurs at a frequency 1.153×10^{11} Hz. Calculate the moment of inertia of CO molecule. **10**
- (b) What is Raman effect? How does it differ from Rayleigh scattering? Explain Raman effect on the basis of quantum mechanical theory. How is Raman effect experimentally studied? What are the advantages of using laser sources in the study of Raman effect? **30**

SECTION 'B'

5. (a) Calculate the packing fraction and the binding energy per nucleon for $^{16}_8O$ and $^{87}_{38}Sr$ nuclei. **10**
- (b) Explain the reduced zone scheme of plotting the energy bands in solids. On the basis of E vs k curve distinguish between conductors, semiconductors and insulators. **10**
- (c) State the quantum numbers I_z , Y and S for the uds quarks and antiquarks. Which combination of these leads to the formation of (i) proton and (ii) neutron? **10**
- (d) What is Josephson tunneling? Distinguish between a.c. and d.c. Josephson effects. **10**
- (e) A star converts all its hydrogen to helium, achieving 100% helium. It then converts the helium to carbon via the reaction
- $$^4_2He + ^4_2He + ^4_2He \rightarrow ^{12}_6C + 7.27 \text{ MeV.}$$
- The mass of the star is 5.0×10^{32} kg and it generates energy at the rate of 5×10^{30} W. How long will it take to convert all Helium to carbon at this rate? **10**
- (f) Identify the above op-amp circuit. Estimate the net output voltage V_0 .
[Figure (printed above the text of part (f)): Op-amp circuit. A 2 V source (battery, + terminal up, - terminal grounded) is connected through a 10 K resistor to the inverting (-) input, pin 2, of the op-amp. A 20 K feedback resistor connects the output, pin 6, back to the inverting input (pin 2). The non-inverting (+) input, pin 3, is connected directly to the + terminal of a second 2 V source whose - terminal is grounded. Supply pins: pin 7 to +15 V, pin 4 to -15 V. The output at pin 6 is V_0 .] **10**
6. (a) What are magic numbers? Discuss shell structure of a nucleus. How is this model able to explain various properties of nuclei? Discuss the limitations of this model. **25**
- (b) Predict from the single particle shell model the shell configuration, ground state spin and parity for the following nuclei: $^{13}_7N$; $^{17}_8O$ **10**
- (c) Explain parity violation in β -decay. Describe how parity violation was experimentally detected in the decay of ^{60}Co . **25**
7. (a) What is nearly free electron approximation? On the basis of this approximation explain the formation of energy bands in solids. **20**
- (b) Distinguish between Einstein and Debye models of specific heats of solids. Obtain an expression for the specific heat of a solid on the basis of Debye model. Discuss the results for low and high temperature ranges. **20**
- (c) Distinguish between classical and quantum theory of paramagnetism. Explain the paramagnetism of free electrons on the basis of F. D. distribution. **20**

8. (a) Draw a two stage RC coupled transistor amplifier. Plot the frequency response and indicate the lower and upper cut off frequencies and the bandwidth. **30**
- (b) Give the basic structure of a n-channel depletion type MOSFET. Draw the drain current–drain voltage characteristics both in depletion as well as in enhancement modes. **15**
- (c) Why NAND and NOR gates are called universal gates? Give the logic diagram, Boolean equation and the truth table of a NAND gate. Design an OR gate using only NAND gates. **15**