

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. Attempt any three of the following:
 - (a)(i) Explain what do you understand by Heisenberg uncertainty principle. Using this principle, determine the energy of the ground state of a one dimensional simple harmonic oscillator. 10
 - (a)(ii) An electron having an energy 2 eV is travelling in the region where $V(x)$ varies as shown below: Calculate the de Broglie wavelength of the electron in regions I, II and III.
 [Figure: Potential V (vertical arrow) against x , with the electron incident from the left (arrow labelled $E = 2$ eV). Region I (left): $V = 0$ (solid horizontal line). Region II (middle): a rectangular well of depth 10 eV, the depth marked by a double arrow labelled -10 eV below the $V = 0$ level (shown dashed across the well). Region III (right): a step of height 1 eV above the $V = 0$ level, the height marked by a double arrow labelled 1 eV.] 10
 - (b)(i) Express the Cartesian components of the angular momentum L in operator form. Show that $[L^2, L_z] = 0$. What is the significance of this commutation relation? 15
 - (b)(ii) Show that the Pauli Matrices anti-commute. 5
 - (c)(i) What are the typical energies (eV) of the radiations, required to excite (i) electronic transitions, (ii) vibrational transitions and (iii) rotational transitions in a molecule? 6
 - (c)(ii) The rotational spectrum of HI consists of equidistant lines with a separation of 12.8 cm^{-1} . Calculate the (a) M.I. and (b) bond length of HI molecule. 14
 - (d)(i) Show that the radial probability density of the ground state of the hydrogen atom has a maximum at $r=a$. The ground state wave function of the hydrogen atom is given by

$$\psi(r) = 1/(\sqrt{\pi}a^{3/2}).e^{-r/a}$$
 where a is the Bohr radius. 10
 - (d)(ii) Calculate the Larmor frequency of a spin $1/2$ particle in a magnetic field B . 10
2. A particle of mass m , with energy E such that $-V_0 < E < 0$, is trapped in a potential well as shown below:
 [Figure: Potential V against x : $V = \infty$ for $x < 0$ (vertical wall at the origin O , arrow marked ∞); $V = -V_0$ for $0 < x < a$ (well floor marked $-V_0$); $V = 0$ for $x > a$ (the x -axis, dashed from O to a and solid beyond a).]
 - (a) Write time independent Schrodinger equation in regions (i) $0 < x < a$ and (ii) $x > a$. 15
 - (b) Obtain an expression from which the energy eigen values can be determined. 15
 - (c) Show that for at least one bound state to exist.

$$a^2 V_0 \geq h^2 \pi^2 / 8m$$
 30

3. (a) Number at non-interacting electrons are confined in a cube of volume L^3 . Obtain an expression for the Fermi energy. 30
- (b) Define the gyromagnetic ratio and obtain an expression for the Lande g factor. What is the importance of g factor in spectroscopy? 30
4. (a) Discuss the salient features of O, P, Q, R and S branches of electronic spectrum of diatomic molecules. Which spectrum contains only branches, both branches and bands, branches and progressions? 25
- (b) Show that a spinning nucleus precesses in a magnetic field. Explain the underlying principle of NMR spectroscopy. The magnetic moment of a proton is $2.793 \mu_N$. Calculate the radio frequency at which nuclear magnetic resonance occurs in water kept in a magnetic field of T. 35

SECTION 'B'

5. Answer any THREE of the following:
- (a) Sketch carefully the binding energy per nucleon curve for stable nuclei. Explain its salient features. On the basis of this curve explain why fusion is possible only for low mass nuclei, whereas fission takes place in heavy nuclei. 20
- (b)(i) State the conservation law which is violated in each of the following processes: (1) $n \rightarrow p + e^- + \bar{\nu}$ (2) $\pi^- + p \rightarrow K^+ + K^-$ (3) $\pi^- + p \rightarrow \Sigma^+ + K^-$ (4) $\Sigma^- \rightarrow K^- + p + \bar{p}$ 8
- (b)(ii) Draw a bcc lattice. Determine its primitive lattice vectors and calculate the packing fraction. 12
- (c) Explain the operation of the following circuit is a gate. Draw the truth table and find the operation carried out by this gate neglecting the source impedance.
[Figure: Diode-transistor logic gate. Three inputs A, B and C, each connected through a diode D to a common node P; the diodes are drawn with their cathodes towards the inputs (anodes at P). An input waveform stepping from 0 V up to 12 V is drawn beside the inputs. Node P is connected to +12V through a 15K resistor. From P a resistor R1 (15K), shunted by a speed-up capacitor C1, goes to the base of transistor Q; the base is also connected to -12V through a 100 K resistor. Q is an npn transistor with its emitter to ground and its collector (C) connected to +12 V through a 2.2 K resistor; the output Y is taken from the collector.]
junction saturation voltages and diode voltages in forward direction. Find the minimum value of h_{fe} . 20
- (d)(i) What are high T_c superconductors? Give two examples indicating their transition temperatures. Differentiate between the conventional and high T_c super conductors. 12
- (d)(ii) Explain the principle of feedback in an amplifier. What are the advantages & negative feedback? 8
6. (a) List some of the important properties of deuteron and show that it is a loosely bound system and has only one bounded state. 30
- (b) Distinguish between a nuclear reaction and decay. Which conservation laws are obeyed in nuclear reactions? Explain the significance of Q value. Calculate the Q value for the following nuclear reaction:
$${}_1^2\text{H} + {}_1^2\text{H} \rightarrow {}_2^3\text{H} + n.$$
 30
7. (a) Give two characteristics properties of strange particles which distinguish them from non-strange ones. Write the Gellmann-Nishijima relation and show how it is used for the classification of elementary particles. 30
- (b) What is a Josephson junction? Discuss dc and ac Josephson effects and obtain the relation.
$$V = 2eV/h$$

where the symbols have their usual meaning. 30

8. (a) Derive the various current components in a p-n-p transistor when it is actively biased. Using Ebers-Moll model, show that for the common-emitter configuration

$$I_C = -\alpha I_E - I_{CO}(e^{V_C/V_T} - 1)$$

where the symbols have the usual meaning.

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- (b) In the following circuit, Show that the stability factor, S, is given by

$$S = (1 + \beta) / (1 + \beta R_e / (R_e + R_b))$$

Where $R_b = R_1 R_2 / (R_1 + R_2)$

[Figure: Printed between “is given by” and the formula: voltage-divider (potential-divider) bias circuit of an npn transistor. R_1 from V_{CC} to the base node and R_2 from the base node to the common (ground) line; the input is coupled to the base through a capacitor. The collector goes to V_{CC} through R_c , and the output is taken from the collector through a coupling capacitor. The emitter goes to the common line through R_e shunted by a bypass capacitor C_1 .]

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- (c) Calculate the gain of the following amplifier circuit: Given that $g_m = 10 \text{ mV/A}$, $r_d = 1 \text{ } \Omega$ and $Z_L = 10 \text{ k}\Omega$.

[Figure: Printed before “Given that”: a FET amplifier (MOSFET symbol in a circle). The drain is connected to a -24 V supply through the load Z_L ; the source is connected to the common (ground) line; the gate is driven by an a.c. signal source (circle with $\sim$) in series with a d.c. bias battery returning to the common line. The output voltage V_o is taken between the drain and the common line.]

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