

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:
 - (a)(i) Calculate the de Broglie wavelength of a thermal neutron at 27 °C temperature. 10
 - (a)(ii) Considering one-dimensional case for free particle, show that the plane wave function is the eigenfunction of a linear momentum operator and kinetic energy operator. 10
 - (b)(i) Using Pauli matrices σ_x , σ_y and σ_z , show that

$$(\boldsymbol{\sigma} \cdot \mathbf{r})(\boldsymbol{\sigma} \cdot \mathbf{p}) = \mathbf{r} \cdot \mathbf{p} + i\boldsymbol{\sigma} \cdot \mathbf{L}$$
10
 - (b)(ii) For the radiation of wavelength 6000 Å, determine the wavelength separation between its two component lines which are observed in the normal Zeeman effect. The magnetic field used is $\pi/4$ weber/m² and the specific charge of the electron = 1.76×10^{11} C kg⁻¹. 10
 - (c) Examine whether the molecule ¹¹B ¹⁶O can show – (i) a pure rotation spectrum; (ii) a vibration-rotation spectrum. Give reasons. 10
 - (d) Determine the order of magnitude of the energy involved in the spin-orbit interaction of 2p state of an atom with an electron. Given the magnetic field due to the state is 0.28 T. 20
2. (a) Distinguish between potential well and potential barrier. Given their illustrations. Considering one dimensional potential step, prove that sum of the reflection and transmission coefficients is unity. 30
 - (b) Prove that

$$d/dt(x) = 1/m(p_x)$$
 Define all the terms of this relation and give its physical interpretation. 30
3. (a) Explain how the problem of the hydrogen atom could be solved using Schrodinger equation. Also derive an expression for its energy eigenvalue and discuss the associated bound states of this case. 40
 - (b) State and discuss the Franck-Condon principle giving special reference to its applications. 20
4. (a) What are the gyromagnetic factors of the three cases, viz., a spinning electron, an orbiting electron and a free proton? 15
 - (b) Explain and discuss the basic principle of nuclear magnetic resonance (NMR). 15
 - (c) In the case of proton NMR, state the expression for the energy of the dipole in an external magnetic field. How does the NMR originate? Give the rough range of frequencies of the NMR signals, and the normal magnitude of the applied field. 30

SECTION 'B'

5. Answer any three of the following: 20
- (a) Based on physical calculations, explain why deuteron is stable. 20
- (b)(i) Discuss in detail the classification of elementary particles. 10
- (b)(ii) On the basis of band theory, explain the classification of solids by considering their electrical properties. 10
- (c)(i) Simplify the logical expression

$$f = ABC + B\bar{C}D + \bar{A}BC$$
 by using Karnaugh map and realise f using NAND gates only. 10
- (c)(ii) The transistor in the following circuit has $\beta = 100$ and $V_A = 90$ V. What value of R_B will give 0 volt d.c. output?
 [Figure: Emitter-follower (common-collector) circuit with an n-p-n transistor. Collector connected directly to the +12 V rail. R_B connected from the +12 V rail to the base. Input V_i applied (input terminal, with a grounded return terminal) through a series coupling capacitor to the base. Emitter connected to the output terminal (output taken between emitter and ground) and through $R_E = 1.2$ k Ω to the -12 V supply. Label: $V_{BE} \approx 0.65$ V.] 10
- (d)(i) Explain the quark structure of hadrons. Identify the field of quark of electro-weak and electro-strong interactions. Also verify the conservation of strangeness in the following reactions:

$$\pi^- + p \rightarrow \Lambda^0 + K^0$$

$$K^+ \rightarrow \pi^+ + \pi^+ + \pi^-$$
 10
- (d)(ii) Drawing necessary diagrams, explain diamond structure and CsCl structures. 10
6. (a) Describe briefly the different types of physical processes with which gamma rays are absorbed by matter as they are emitted. 20
- (b) Illustrate the Geiger-Nuttall law in a plot between the decay constant and energy of various nuclides for any radioactive series. 20
- (c) Name the various classifications of the gamma rays based on electric, magnetic and order. How does parity affect these radiations? 20
7. (a) What is the role of neutrino in the weak interaction of radioactive nuclides? Explain the experimental detection of neutrino. 15
- (b) In the following reactions indicate with an explanation, whether they proceed by strong, electromagnetic or weak interaction or they are forbidden:

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$p \rightarrow n + e^+ + \nu_e$$

$$p + \pi^- \rightarrow K^+ + \Sigma^-$$
 15
- (c) What are Brillouin zones? How are they related to the energy levels of an electron in a metal? Draw the Brillouin zone for a rectangular lattice of sides π and 2π . Also compute the energy at the corner and midpoints of the adjacent sides of the first Brillouin zone. 30
8. (a) The following common-emitter amplifier is required to have a signal voltage gain V_{out}/V_S of at least 100. The transistor has $\beta = 63$, early voltage $V_A = 100$ V and $I_{SE} = 1.5 \times 10^{-14}$ A: Assuming that the operating collector voltage is supposed to be +6 V, perform related calculations to check whether the circuit satisfies the operating point and voltage gain criteria. The reactance of the capacitors can be neglected at all frequencies.
 [Figure: Common-emitter amplifier with an n-p-n transistor. Signal source V_S in series with $R_S = 600$ Ω , coupled through a series capacitor to the base. $R_B = 810$ k Ω from the top (supply) rail to the base; $R_C = 6.8$ k Ω from the top rail to the collector; the supply voltage is not labelled. Emitter connected directly to the common bottom (ground) line, which also returns V_S and R_L . Collector connected to the load $R_L = 10$ k Ω (a small element on this connection, probably a coupling capacitor, is hidden by the watermark [?]); V_{out} taken 20

across R_L (arrow pointing up).]

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| (b) | Explain the working and applications of a FET. | 20 |
| (c) | What is a microprocessor? Explain the internal architecture of an 8085 μ P. | 20 |