[redacted] I.F.S-2009

Sl. No. 8328

B–JGT–J–QIB

PHYSICS

Paper—II

Time Allowed : Three Hours	Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt Question Nos. 1 and 5 which are compulsory, and THREE of the remaining questions, selecting at least ONE question from each Section.

The number of marks carried by each question is indicated at the end of the question.

Answers must be written in ENGLISH only.

Assume suitable data, if considered necessary and indicate the same clearly.

List of Useful Constants

Mass of proton	$= 1 \cdot 673 \times 10^{-27}$ kg
Mass of neutron	$= 1 \cdot 675 \times 10^{-27}$ kg
Mass of electron	$= 9 \cdot 11 \times 10^{-31}$ kg
Planck constant	$= 6 \cdot 626 \times 10^{-34}$ J-s
Boltzmann constant	$= 1 \cdot 380 \times 10^{-23}$ J-K^{-1}
Bohr magneton	$= 9 \cdot 273 \times 10^{-24}$ A-m^2
Electronic charge	$= 1 \cdot 602 \times 10^{-19}$ C
Atomic mass unit (u)	$= 1 \cdot 660 \times 10^{-27}$ kg
	$= 931$ MeV
Velocity of light in vacuum, c	$= 3 \times 10^8$ m-s^{-1}

$m(^{1}_{1}\mathrm{H}) = 1{\cdot}007825$ u

$m(^{2}_{1}\mathrm{H}) = 2{\cdot}014102$ u

$m(^{3}_{1}\mathrm{H}) = 3{\cdot}016049$ u

$m(^{12}_{6}\mathrm{C}) = 12{\cdot}00000$ u

$m(^{20}_{10}\mathrm{Ne}) = 19{\cdot}992439$ u

$m(^{4}_{2}\mathrm{He}) = 4{\cdot}002603$ u

$m(^{1}_{0}n) = 1{\cdot}008665$ u

$m(e) = 0{\cdot}000549$ u

$m(^{152}_{62}\mathrm{Sm}) = 151{\cdot}919756$ u

$m(^{152}_{63}\mathrm{Eu}) = 151{\cdot}91749$ u

$m(^{152}_{64}\mathrm{Gd}) = 151{\cdot}919794$ u

$m(^{35}\mathrm{Cl}) = 35{\cdot}450$ u

Unless otherwise indicated, symbols and notations have usual meanings.

Section—A

1. Answer any *four* of the following :

(a) The wavelength and frequency of a guided wave are related by

$$\lambda = c / \sqrt{\nu^2 - \nu_0^2}$$

Express the wave's group velocity v_g in terms of c and its phase velocity v_p. 10

(b) What is the minimum angle that the angular momentum vector may make with the z-axis, in the case of $l = 3$? How many levels are possible? Show the angle in a vector diagram. 10

(c) An H ^{35}Cl molecule is found to have a fundamental vibration at $2885 \cdot 9\ \text{cm}^{-1}$. Its internuclear distance changes by $0 \cdot 05$ nm. What will be the change in potential energy? 10

(d) Calculate the Zeeman energy splitting of the $2P_{1/2}$ and $2S_{1/2}$ states in sodium for a magnetic field of 2 T. 10

(e) If $\hat{\sigma}_x, \hat{\sigma}_y$ and $\hat{\sigma}_z$ are Pauli spin matrices, prove the following relationship : 10

$$\sin(\hat{\sigma}_x \phi) = \hat{\sigma}_x \sin\phi$$

2. (a) The wave function of a quantum particle is $\psi(x) = Ae^{i(\alpha x - \alpha^2 \hbar/2m)}$. Find $\langle p_x \rangle$. 10

(b) For the $E < U_0$ potential barrier, obtain expression for the probability that the particles will be transmitted resonantly.

$$U(x) = \begin{cases} 0 & x < 0,\ x > L \\ U_0 & 0 < x < L \end{cases}$$ 20

(c) If an electron is incident on a barrier potential $0 \cdot 100$ eV and width 15 nm in the problem *(b)* above, calculate the transmission probability, if its energy is $0 \cdot 060$ eV. 10

3. *(a)* Prove that $\hat{L}^2 = \hat{L}_x^2 + \hat{L}_y^2 + \hat{L}_z^2$ commutes with all the three components of angular momentum operator $\hat{L}$. 20

(b) Discuss briefly the Stern-Gerlach experiment with the help of a diagram. Analyse the outcome of this experiment. 20

4. *(a)* Discuss the number of fundamental vibrations of water molecule. 15

(b) Frequency separation between adjacent lines in the rotational spectrum of $^{35}Cl\,^{19}F$ is measured as 11·2 GHz. Calculate the interatomic spacing. 15

(c) The NMR spectrum of CH_3I taken in a 60 MHz spectrometer gave a strong signal at 130 Hz and chemical shift 2·16 ppm. Obtain the absorption frequency, if the spectrum were to be made in a 90 MHz spectrometer. What would be the chemical shift in the new spectrum? 10

Section—B

5. Answer any *four* of the following :

(a) *(i)* What is the *Q*-value of the reaction $^{152}Eu\,(n, p)^{152}Sm$? 5

(ii) What type of weak interaction can occur for ^{152}Eu ? 5

(b) Lead shows superconductivity at 7·19 K for zero applied magnetic field. When magnetic field of 0·08 T is applied, superconductivity will not take place at any temperature. Calculate the applied magnetic field that will stop superconductivity at 2·0 K. 10

(c) What is internal conversion? Show that the internal conversion coefficient depends upon the atomic number of the nucleus. 10

(d) Indicate with reasons, why each of the following high-energy reactions/particle decays is either allowed or forbidden : 10

(i) $\pi^- + p \rightarrow \pi^0 + n$

(ii) $\pi^0 \rightarrow \gamma + \gamma + \gamma$

(iii) $\pi^0 \rightarrow \gamma + \gamma$

(iv) $\pi^+ \rightarrow \mu^+ + \nu_\mu$

(v) $\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu$

(e) Write down the quark composition of the following : 10

(i) Neutron (n)

(ii) Proton (p)

(iii) Sigma-plus (Σ^+)

(iv) Kaon-zero (K^0)

(v) Pion-zero (π^0)

6. *(a)* Derive an expression for the recoil energy loss in the emission of gamma ray. What is natural line width? Explain. 10

(b) What is Mössbauer effect? Define the Mössbauer parameters—isomer shift, quadrupole splitting and magnetic splitting. 20

(c) For atomic transitions, resonance fluorescence and absorption are normal, but in nuclear gamma decay this does not occur. Why? Explain with a typical illustrative example. 10

7. *(a)* Discuss Grand Unified Theory schemes for Strong, Weak and Electromagnetic interactions. What are experimentally verifiable predictions of such schemes? 20

(b) Explain Kronig-Penney model for the motion of an electron in a periodic one-dimensional square well potential. Show from the energy band diagram that the materials can be classified as conductor, semiconductor and insulator. 20

8. *(a)* Calculate the resistivity of silicon having atomic mass 28, and having density of $2 \cdot 42 \times 10^3$ kg-m^{-3} and a valence of 2. Assume that the Fermi energy for

silicon is 2 eV. (Assume electron mean free path to be 100 times the interatomic spacing.) 20

(b) Discuss the construction and operation of Enhancement MOSFET and Depletion MOSFET. Give their characteristics. How do they differ from JFET ? 20

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