2023

(May/June)

PHYSICS

(Honours)

(Atomic Physics—II, Molecular Spectroscopy, Nuclear Physics—II, Astrophysics)

[PHY–06 (T–B)]

Marks : 56

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** and *any* **four** from the rest

1. *(a)* A spectral line of wavelength 6000 Å shows a separation of 0·2 Å between the component lines in a normal Zeeman pattern when subjected to a magnetic field of flux density 1·2 Wb/m^2. Calculate the value of e/m for the electron. 4

(b) Calculate the Q-value of the following nuclear reaction :

$$^{14}_{7}N + \alpha \rightarrow ^{17}_{8}O + p$$

where $m_p = 1{\cdot}0078$ u, $m_\alpha = 4{\cdot}0026$ u, $m_N = 14{\cdot}0031$ u, $m_O = 16{\cdot}9994$ u and 1 u = 931 MeV. 2

(c) Consider the following strong interaction :

$$\pi^- + p^+ \rightarrow \Lambda^\circ + \pi^\circ$$

Is it an allowed or a forbidden reaction? Justify your answer by using suitable conservation laws. 2

2. (a) Explain the salient features of the vector atom model. Briefly explain the experiment which provides evidence in support of this model. 2+3=5

(b) What are quantum numbers? Give the physical interpretation of the quantum numbers involved in completely defining a quantum state of the atom. 5

(c) Calculate the values of L and J for the states (i) $^1S_0$ and (ii) $^2D_{3/2}$. 2

3. (a) Describe the main features of the alkali spectrum. What is the effect of spin-orbit interaction on this type of spectrum? 2+1=3

(b) Briefly explain L-S and J-J coupling for a two-electron atomic system. Find all the possible spectral terms for calcium ($Z = 20$) using L-S coupling in the sp configuration. 4+2=6

(c) State and prove Larmor's theorem and write down the expression for Larmor's frequency. 2+1=3

4. (a) What are the three types of molecular spectra? Mention the region of electromagnetic spectrum in which they belong. 1½+1=2½

(b) Consider a vibrating diatomic molecule as a harmonic oscillator. Obtain the expression for the allowed or quantized energy levels for this molecule. Explain why molecules like HCl show vibrational-rotational spectra whereas molecules like H_2 do not. 4½+2=6½

(c) With the help of a schematic diagram, discuss the Frank-Condon principle in electronic band spectra. 3

5. (a) Give a brief and qualitative quantum mechanical explanation of the Raman effect. 4

(b) A Raman line is observed at 4768·5 Å when the substance was excited by a 4358·3 Å radiation. Calculate the vibrational frequency in cm^{-1} that causes this Raman line. 2

(c) Describe the principle of working of atomic emission spectroscopy and atomic absorption spectroscopy. 3+3=6

6. (a) What is meant by binding energy of a nucleus? Deduce an expression for the binding energy of a nucleus. 1+2=3

(b) Give three main evidences that support the nuclear shell model of nuclei. 3

(c) Describe the Fermi's theory of β-decay. 6

7. (a) Distinguish between nuclear fission and nuclear fusion. Explain the energy released in the two processes from the binding energy curve. 2+2=4

(b) Discuss the carbon-nitrogen cycle for the production of stellar energy. 4

(c) Briefly explain the four different types of fundamental interactions by mentioning their strengths and ranges. 4

8. (a) Describe how muons and pions were discovered in cosmic-ray showers. How was the mass of muons established? 2+2=4

(b) What are resonance particles? How are they produced? 1+1=2

(c) Give a brief outline of the three different types of the end products of stellar evolution. 4

(d) What are Cepheid variables? What are their two main classes? 1+1=2

★★★