Ref. : SC/UG/GE/PHY/TH/04/2023

BSc 2nd Year 2nd Semester Examination - 2023

Subject : Modern Physics

Full marks : 40; Time : 02 Hours

IMPORTANT : Put corresponding question numbers against your answers. Make your answers brief and to the point. There may be partial marking on correct steps, even in the case when the final answer is either not obtained or found to be wrong. The symbols used below will carry their usual meaning, unless otherwise stated.

Group A, Quantum Physics (Answer any TWO)

1. (a) Deduce Planck's radiation formula. Discuss the new ideas introduced by Planck to explain the energy distribution of black body radiation. **(5)**

(b) Prove that in the limits of very long wavelength, Planck's formula reduces to Rayleigh-Jeans formula. **(3)**

(c) A quantum oscillator in the cavity of a black body is vibrating at a frequency of 5.0×10^{14} Hz. Calculate the spacing between its energy levels. **(2)**

2. (a) Derive the Compton's formula for the wavelength shift $\Delta\lambda$ of X-ray photons when scattered from a target material. **(6)**

(b) A 71-pm X-ray is incident on a calcite target. Find the wavelength of the X-ray after getting scattered from the target at a 30° angle. What is the largest shift that can be expected in this experiment? [1 pm = 10^{-12} m] **(4)**

3. Consider a quantum mechanical particle free to move within a one dimensional rigid box of length L.
a) Write the time independent Schrödinger equation for the particle. **(2)**

b) What are the boundary conditions? **(1)**

c) Plot the normalized wave function for $n = 1, 2, 3$. **(3)**

d) Find the expectation values for position and momentum of the particle. **(2+2)**

Group B, Nuclear Physics (Answer any TWO)

4. (a) Define isobar and isotone. **(1)**

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(b) Explain the four different kind of forces or interactions seen in nature and mention their characteristic length scales. **(3)**

(c) Write down the empirical formula for the nuclear radius as a function of the mass number and draw the corresponding curve. **(2)**

5. (a) What is nuclear binding energy? Draw the binding energy per nucleon versus the atomic number curve. In which region the nucleus is most stable? **(2.5)**

(b) Explain in detail the Coulomb term of the semi-empirical mass formula. **(3.5)**

6. (a) Derive the decay formula for the number of nucleus $N(t)$ at a given time, t. Hence explain half life and the mean lifetime. **(3)**

(b) Briefly explain α, β and γ decay. For which of these three the nucleus of an element does not change? **(3)**

Group C, Crystal Structure (Answer any ONE)

7. (a) "All primitive cells are unit cells but all unit cells may or may not be primitive cell". Justify the statement. **(2)**

(b) What is atomic packing factor? Calculate the packing factor of a fcc crystal structure. **(2)**

8. (a) Is it possible to use visible light to study crystal structure using Bragg's diffraction? Explain. **(2)**

(b) Draw the (110) crystallographic plane and direction of a simple cubic crystal. **(2)**

Group D, Magnetic Materials (Answer any ONE)

9. (a) What are the differences between ferromagnetic and antiferromagnetic materials? **(2)**

(b) Draw the magnetic susceptibility versus temperature curves of ferro- and anti-ferromagnetic materials. **(2)**

10. (a) What is Curie temperature? Explain. **(2)**

(b) The Curie temperature of a ferromagnetic material is $300K$. If the magnetic susceptibility of the material is 0.6 at $450K$ temperature, then find out the Curie constant. **(2)**