WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2022

PHSACOR09T-PHYSICS (CC9)

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) The half-life of a certain excited state is about 8 ns. If this is essentially the uncertainty Δt for photon emission, calculate the uncertainty in frequency $\Delta\nu$, assuming that $\Delta E\Delta t \approx h$. Find $\Delta\nu/\nu$ if the photons have $\lambda = 500$ nm.

(b) Assuming spherical shape of atomic nucleus, show that density of nuclear matter is constant.

(c) Calculate the de Broglie wavelength for a helium atom in a furnace at 400 K for which the kinetic energy is $3kT/2$.

Given M_{He} = 4.002602 u

1u = 931 MeV

(d) A muon is travelling through the laboratory at a speed of $3c/5$. How long does it last?

(e) Write down the important characteristics of nuclear force.

(f) Why do not we observe a Compton effect with visible light?

(g) What is a metastable state? What role do such states play in the operation of a laser?

(h) Find the total angular momentum and parity for the ground sate of $_6C^{13}$ nucleus.

(i) A proton is accelerated in a synchrotron until its kinetic energy is just equal to its rest mass (938 MeV). Find the ratio v/c for this proton.

(j) Derive Rayleigh-Jeans formula from Wien's formula in case of blackbody radiation.

(k) Calculate the binding energy and packing fraction for helium. The atomic masses of proton, neutron and helium are 1.00814 u, 1.00898 u and 4.00387 u respectively. [1u = 931 MeV]

(l) Show that it is impossible for a photon to transfer all its energy to a free electron.

(m) Why is the existence of electron within a nucleus ruled out?

(n) What are the processes by which γ-ray interacts with matter? Mention their Z-dependence.

2. (a) Deduce Planck's radiation law in the form 4+3

$$u_\lambda = \frac{8\pi ch}{\lambda^5} \cdot \frac{1}{e^{ch/\lambda kT} - 1}$$

and show that,

$$u = \int_0^\infty u_\lambda d_\lambda = \frac{8\pi^5 k^4 T^4}{15 c^3 h^3}$$

u is energy density of a black body at temperature T K.

(b) When U^{235} captures a slow neutron, it fissions. If the fission products are Rb^{92} and Cs^{140}, how many neutrons are emitted? If the masses of U^{235}, Cs^{140} and Rb^{92} are 234.043915 u, 139.917110 u and 91.919140 u respectively, find the energy released in this particular fission. 3

3. (a) A 5.30 MeV α-particle happens, by chance, to be headed directly towards the nucleus of an atom of gold (Z = 79). How close does it get before it comes momentarily to rest and reverses its course? Neglect recoil of the gold nucleus. 3

(b) (i) Show that the electrostatic potential energy of a uniform sphere of charge Q and radius R is given by $U = 3Q^2/20\pi\varepsilon_0 R$ 3+2+2

(ii) Find the electrostatic potential energy for the nuclide ^{239}Pu, assumed spherical.

(iii) Compare its electrostatic potential energy per particle with its binding energy per nucleon of 7.56 MeV.

4. (a) Mention the postulates of special theory of relativity given by Einstein. 2

(b) Deduce the Lorentz transformations using simple relation between space and time. 4

(c) Find the maximum kinetic energies of photo-electrons ejected from a potassium surface, for which threshold energy is 2.1 eV, by photons of wavelengths 2000Å and 3000Å. What is the threshold frequency γ_0 and the corresponding wavelength? 2+2

5. (a) A cosmic ray photon of energy $h\nu$ is scattered through 90º by an electron initially at rest. The scattered photon has a wavelength twice that of the incident photon. Find the frequency of the incident photon. 2

(b) Establish the relation between the angle of scattered photon and recoil angle of the electron in Compton scattering. Hence find out the recoil angle of the electron in problem 5(a). 3+1

(c) Mention the basic features of nuclear shell model and discuss the significance of magic numbers with respect to stability of nuclei. 2+2

N.B. : *Students have to complete submission of their Answer Scripts through E-mail / Whatsapp to their own respective colleges on the same day / date of examination within 1 hour after end of exam. University / College authorities will not be held responsible for wrong submission (at in proper address). Students are strongly advised not to submit multiple copies of the same answer script.*

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