WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2020

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) Determine the velocity at which a particle has to move so that the relativistic mass of the particle is twice its rest mass.

(b) Show that $x^2 + y^2 + z^2 - c^2t^2$ is invariant under Lorentz transformation. Symbols are of usual significance.

(c) A civil engineer measures a street to be $L = 100$ m long in Earth frame (assumed to be an inertial frame). Use the Lorentz transformation to obtain an expression for its length measured from a spaceship S', moving at a speed $0.20c$ in a direction parallel to the street.

(d) Write down the Rayleigh-Jeans formula for classical blackbody radiation, explaining each term. Demonstrate "ultraviolet catastrophe" from the formula.

(e) Write down the expression of the change in wavelength of the scattered light in case of Compton scattering in terms of the mass of the scatterer and fundamental constants. Find the value of the maximum change.

(f) Using the principle of uncertainty find out the minimum energy of a particle of mass *m* confined in a small cube of length *a*.

(g) Using De Broglie formulation, show that the group velocity of a wave packet corresponding to a particle is equal to the velocity of the particle.

(h) If a certain metal with a work function of $W = 2.5$ eV is illuminated by a monochromatic light of wavelength 3500 Å. What is the maximum kinetic energy of the electrons ejected in the photoelectric effect?

(Given, Planck constant $h = 6.63\times10^{-34}$ Js, speed of light in vacuum $c = 3\times10^{8}$ m/s, charge of an electron $e = 1.6\times10^{-19}$ C).

(i) An excited atom radiates energy of a characteristic frequency and comes down to the ground state. If the average time gap between the excitation of the atom and the time it radiates is 1×10^{-8} s then estimate the inherent uncertainty in the frequency of the emitted radiation.

(j) Define four velocity and express its relation with three velocity.

(k) Is the reaction $p \rightarrow n + e^{+} + \bar{\nu}_e$ possible? Give reasons.

(l) Why are the α-particles, rather than protons and neutrons, emitted from radioactive nuclei?

(m) Sketch schematically the *N*-*Z* plot where *N* is the neutron number and *Z* is the atomic number. Briefly explain the significance of the plot.

(n) Find out the relation between the mean life time and half life time of a radioactive decay.

2. (a) Show that it is impossible for a photon to transfer all its energy to a free electron. 2

(b) Show that the de Broglie wavelength of a particle of rest mass m_0 and kinetic energy *T* is given by the relativistic formula $\lambda = \frac{hc}{\sqrt{T^2 + 2m_0c^2T}}$. 3

(c) A charged π-meson (rest mass = $273m_e$) at rest decays into a muon (rest mass = $207m_e$) and a neutrino (zero rest mass), where m_e denotes the rest mass of electron. What is the energy of the emitted neutrino? 3

(d) A system has only two possible non-degenerate energy levels E_1 and E_2. The system is in equilibrium at a temperature *T* and $p(E)$ is the probability that the system is at an energy *E*. Show that $p(E_2) = \frac{1}{1+\exp\left(\frac{\Delta E}{k_B T}\right)}$, where $\Delta E = E_2 - E_1$. 2

3. (a) Energy required to dislodge a bound electron from sodium is 2.3 eV. Calculate the threshold wavelength of the light for the photoelectric effect to occur. How long the light is to be shined on the surface of the metal to observe the photoelectrons? 2+1

(b) If the position of a quantum particle is located using a gamma ray microscope then deduce the relation between the uncertainties in position and momentum of the particle. 4

(c) What is the probabilistic interpretation of wave function associated with a particle? If the wave function of a particle is given by $\psi(x) = A\exp(ikx)$, show that its momentum is exactly known but its position is completely uncertain. 1+2

4. (a) An incandescent lamp is operating at a temperature of 1000 K at an operating frequency of 5.2×10^{14} Hz. Calculate the ratio of stimulated emission rate to spontaneous emission rate. Value of $h = 6.63\times10^{-34}$ Js and $k_B = 1.38\times10^{-23}$ JK^{-1}. 2

(b) Calculate the mass of 1 Curie of ^{234}U. Half life of ^{234}U is 245,000 years. 2

(c) Why is the existence of electron within a nucleus ruled out? 2

(d) Explain how the neutrino hypothesis solves the apparent breakdown of conservation of energy and momentum in beta decay. 2

(e) 'Although the efficiency of a four level laser is less than that of a three level laser, still a four level laser is better than a three level laser.' — Why? 2

5. (a) How long does it take for 60% of a sample of radon to decay? Given that the half life of radon is 3.8 days. 3

(b) Draw schematically the nuclear binding energy curve. Hence explain nuclear fission and fusion. 1+4

(c) What is the need of moderators in a nuclear reactor? 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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