RAMAKRISHNA MISSION VIDYAMANDIRA
(Residential Autonomous College affiliated to University of Calcutta)
B.A./B.Sc. FOURTH SEMESTER EXAMINATION, AUGUST 2021
SECOND YEAR (BATCH 2019-22)
PHYSICS (Honours)
Paper : X [CC 10]

Date : 11/08/2021
Time : 11.00 am – 1.00 pm
Full Marks : 50

UNIT - I

Answer **any five** questions [5×10]

1. a) Suppose that a light of total intensity 1.0 $\mu W/cm^2$ falls on a metallic sample whose area is 1.0 cm^2. Assume that the metallic sample reflects 96 % of the light and that only 3.0 % of the absorbed energy lies on the violet region of the spectrum above the threshold frequency.

   i) What intensity is actually available for the photoelectric effect? [3]

   ii) Assuming that the photons in the violet region have an effective wavelength of 250 nm, how many electrons will be emitted per second? [2]

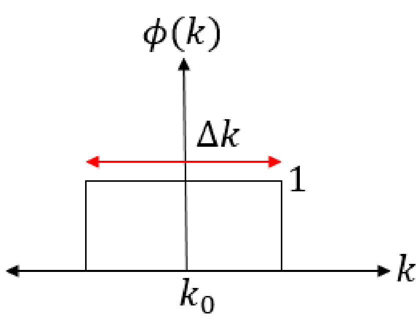
   b) Given a metal whose work function is 4.05 eV. A radiation of wavelength $\lambda = 290\ nm$ falls on it. What is the stopping potential required to stop the most energetic emitted photoelectrons. [5]

2. a) Phase velocity of deep water waves having wavelength λ is given by

$$v_p = \sqrt{\frac{g\lambda}{2\pi}}$$

   Where g is the acceleration due to gravity and v_p is the phase velocity. Show that the group velocity v_g is one-half of the phase velocity. [5]

   b) The amplitude distribution $\phi(k)$ of a matter wave packet is a rectangular pulse of height unity, width Δk and centred at k_0 as shown below



   Show that the matter wave packet has the form [5]

$$\psi(x) = \frac{\Delta k}{\sqrt{2\pi}} \frac{\sin\left(\Delta k \cdot \frac{x}{2}\right)}{\Delta k \cdot \frac{x}{2}} e^{ik_0 x}$$

3. a) The time after which an excited atom radiates is $\tau = 1.0 \times 10^{-8}$ s. Use the uncertainty principle to determine the line width Δf of the emitted light. [5]

b) The wave function of a particle is $\psi(x) = C\, e^{-\frac{|x|}{x_0}}$

Where C and x_0 are constants.

i) Normalize the wave function. [2]

ii) Determine the probability that the particle will be found in the interval $-x_0 < x < x_0$. [3]

4. a) An electron inside an atom can be thought of as a particle inside and infinitely deep square well. If the radius of the atom is 0.1 nm, determine the energy required to excite an electron from $n = 1$ to $n = 2$ state. [5]

b) Consider a particle inside an infinite square well of width L. If the particle is in its ground state, determine the probability of finding the particle in the region $\frac{L}{4} \leq x \leq \frac{3L}{4}$ inside the infinite square well. [5]

5. a) A radioactive substance of half life 100 days which emits β-particles of average energy 5×10^{-7} ergs is used to drive a thermoelectric cell. Assuming the cell to have an efficiency 10%, calculate the amount (in gram-molecules) of radioactive substance required to generate 5W of electricity. [4]

b) Estimate the kinetic energy of the nucleon where it is given that the nuclear radius is about 5×10^{-13} cm and the mass of a proton is about 2×10^{-24} g. [3]

c) In general only the heavier nuclei tend to show alpha decay. For large A it is found that $B/A = 9.402 - 7.7 \times 10^{-3} A$. Given that the binding energy of alpha particles is 28.3MeV, show that alpha decay is energetically possible for $A > 151$. [3]

6. a) For the nucleus ^{16}O the neutron and proton separation energies are 15.7 and 12.2MeV, respectively. Estimate the radius of this nucleus assuming that the particles are removed from its surface and that the difference in separation energies is due to the Coulomb potential energy of the proton. [3]

b) $_{13}Al^{28}$ decays to $_{14}Si^{28}$ via $\beta-$ emission with $T_{max} = 2.865$MeV. $_{14}Si^{28}$ is in the excited state which in turn decays to the ground state via γ -emission. Find the γ -ray energy. Take the masses Al^{28} = 27.981908 amu, Si^{28} = 27.976929 amu. [3]

c) Show that the specific ionization of 480MeV α-particle is approximately equal to that of 30MeV proton. [2]

d) Calculate the thickness of aluminum in g cm^{-2} that is equivalent in stopping power of 2 cm of air. Given the relative stopping power for aluminum S = 1700 and its density = 2.7g cm^{-3}. [2]

7. a) If the binding energies of the mirror nuclei $21Sc^{41}$ and $20Ca^{41}$ are 343.143V and 350.420MeV respectively, estimate the radii of the two nuclei. [3]

b) $_{13}N$ is a positron emitter with an end-point energy of 1.2MeV. Determine the threshold of the reaction $p + 13\ C \rightarrow 13\ N + n$, if the neutron – hydrogen atom mass difference is 0.78MeV [3]

c) Assume that in each fission of $_{235}U$, 200MeV is released. Assuming that 5% of the energy is wasted in neutrinos, calculate the amount of $_{235}U$ burned which would be necessary to supply at 30% efficiency, the whole annual electricity consumption in the area is 50×10^9 kWh. [4]

8. a) i) It is estimated that the deuterons have to come within 100 fm of each other for fusion to proceed. Calculate the energy that the deuterons must possess to overcome the electrostatic repulsion.

ii) If the energy is supplied by the thermal energy of the deuterons, what is the temperature of the deuteron? [3+2]

b) Radium being a member of the uranium series occurs in uranium ores. If the half lives of uranium and radium are respectively 4.5×10^9 and 1620 years, calculate the relative proportions of these elements in a uranium ore, which has attained equilibrium and from which none of the radioactive products have escaped. [3]

c) In the Helium-Neon laser (three-level laser), the energy spacing between the upper and lower levels $E2 - E1 = 2.26$ in the neon atom. If the optical pumping operation stops, at what temperature would the ratio of the population of upper level $E2$ and the lower level $E1$, be 1/10? [2]

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