UNIVERSITY OF NORTH BENGAL
B.Sc. Honours 4th Semester Examination, 2022

CC9-PHYSICS

ELEMENTS OF MODERN PHYSICS

Time Allotted: 2 Hours   Full Marks: 40

The figures in the margin indicate full marks.
All symbols are of usual significance.

GROUP-A

1.   Answer any *five* questions from the following: 1×5 = 5

   (a) Calculate the energy of a Photon of wavelength 6000 Å.   1
   (b) What do you mean by ultraviolet catastrophe?   1
   (c) The uncertainty in the location of a particle is equal to its de-Broglie   1
       wavelength. Show that the uncertainty in its velocity is equal to its velocity.
   (d) How does the radius of a nucleus depend on the corresponding atomic number?   1
   (e) What kind of electrons are involved in photoelectric effect?   1
       (i) free   (ii) bound   (iii) both
   (f) What is threshold energy of a nuclear reaction?   1
   (g) Why slow neutrons can interact with U^{235}, while the fast ones cannot?   1
   (h) Explain spontaneous and stimulated emission.   1

GROUP-B

Answer any *three* questions from the following   5×3 = 15

2. (a) Explain why we do not get Compton effect with visible radiation.   2
   (b) Explain why the Scattered X-ray, having the same wavelength as the incident   1
       X-ray, can be observed at any Scattering angles, in case of Compton effect?
   (c) Show that the de-Broglie wavelength (λ) associated with an electron in an   2
       accelerating potential V is equal to $k/\sqrt{V}$, where k is a constant.

3. (a) State and explain Heisenberg's uncertainty relation.   2
   (b) Using uncertainty relation, show that electron cannot be a constituent of atomic 3
       nucleus.

4.   The wave function of an one dimensional quantum mechanical system is given   1+2+2
     by $\psi(x) = A\sin\dfrac{\pi x}{L}$, for $0 \le x \le L$ and $\psi(x) = 0$ elsewhere.
     Sketch the wave function. Find the constant A and determine the probability of
     finding the system in a region $0 \le x \le L/2$.

5. (a) Sketch *N-Z* plot, where *N* is the nuclear number and *Z* is the atomic number. 2
       Briefly explain the nature of the plot.

(b) 1 gm of Ra is reduced to 2.1 mg in 5 years by α-decay. Calculate the half life of Ra. — 3

6. What do you mean by Einstein's *A, B* coefficients? Show that their ratio is $A_{nm}/B_{nm} = 8\pi h \nu^3/c^3$, where the symbols have their usual significance. — 2+3

GROUP-C

Answer any *two* questions from the following — $10\times2 = 20$

7. (a) Write down Einstein's equation in photoelectric effect explaining the terms involved. — 2

(b) Explain the following in photoelectric effect: — $2\frac{1}{2}+2\frac{1}{2}$
   (i) dependence of photoelectric current on the intensity of incident radiation;
   (ii) dependence of stopping potential on the wavelength of incident radiation.

(c) Show that the kinetic energy T of an electron, having de-Broglie wavelength equal to Compton wavelength, is given by $T = m_0 c^2 (\sqrt{2}-1)$ where m_0 is the rest mass of the electron and c is the velocity of light in vacuum. — 3

8. (a) What do you mean by probability current density for a quantum mechanical system? — 2

(b) Deduce the expression of probability current density of a particle moving in one dimension. — 3

(c) Deduce the equation of continuity for a quantum mechanical dynamic system. — 3

(d) A particle moving in one dimension is represented by $\psi(x) = \left(\dfrac{\sqrt{2}}{\hbar}\right)^2 \dfrac{x+ix}{x+ix^2}$.
   Show that the probability of finding the particle is maximum at $x = \pm 1$. — 2

9. (a) A beam of particles, each of mass m and energy E, moving through a region of zero potential energy, approaches a rectangular potential barrier of width '*a*' and height V_0, where $V_0 > E$. — 6

   If $\beta a \gg 1$, where $\beta = \sqrt{\dfrac{2m(V_0-E)}{\hbar^2}}$, prove that the transmission coefficient is given by $T = \dfrac{16E}{V_0}(1-E/V_0)e^{-2\beta a}$.

(b) When a U-235 nucleus undergoes fission, 200 MeV energy is released. How many fissions per second is needed for generating a power of 1 watt? How much energy in Joule will be released when 1 g of U-235 is fissioned? — 4

10.(a) What are the basic similarity between a liquid drop and an atomic nucleus? — 3

(b) What is mass parabola? How can we predict the stability of an element in a isobaric family? — 2+2

(c) In a radioactive decay process, if λ_1 and λ_2 are the decay constant of parent and daughter nucleii respectively, find the time at which the number of daughter nucleii becomes maximum. — 3

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