WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 5th Semester Examination, 2020, held in 2021

PHSADSE03T-PHYSICS (DSE1/2)

NUCLEAR AND PARTICLE PHYSICS

Time Allotted: 2 Hours | Full Marks: 50

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 ***fifteen*** questions from the following: 2×15 = 30

(a) What are isotones? Give an example.

(b) What is meant by 'saturation' of nuclear force?

(c) What does non-zero quadrupole moment of a nucleus signify? Additionally, what does its sign indicate?

(d) Which nuclei would you expect to be more stable – $^{7}Li_{3}$ or $^{8}Li_{3}$? Justify your answer.

(e) Using the extreme single particle shell model determine the ground state spin-parity of $^{25}Mg_{12}$.

(f) What is meant by 'internal conversion'?

(g) Complete the nuclear reaction $^{15}N_{7}$ (p, d), including the compound nucleus in the intermediate stage.

(h) Explain very briefly how Coulomb interaction affects the probabilities of β^{+} and β^{-} decays.

(i) What is the most common way of absorption of low energy γ-rays? What are the other methods of absorption of γ-rays in matter?

(j) What are the reasons for straggling of range of α-particles?

(k) Explain why electrons cannot be a part of a nucleus.

(l) In connection with strong force, what are charge independence and charge symmetry?

(m) Define range of an α-particle in a medium. Why is it expressed in kg/m^2 unit?

(n) What is pair production? Why cannot it take place in vacuum?

(o) Calculate the energy released by fission of 1 kg of ^{235}U in kWh. Given: Energy released per fission is 200 MeV and Avogadro's number is 6.03×10^{23}.

(p) What is nuclear magneton? Write down its expression.

(q) The isospin, baryon number, and strangeness of a particle are given by $I = 0$, $B = +1$ and $S = -3$ respectively. Find the electric charge of the particle.

(r) What are the quark contents of a proton and an electron?

(s) Define Q-value of a nuclear reaction.

(t) In case of intrinsic spin of a neutron, what is the gyromagnetic ratio? Comment on the value.

2. (a) What do you mean by binding energy of a nucleus? Write down its formal expression. Show graphically the variation of average binding energy per nucleon with mass number and hence discuss the stability of a nucleus. 2+3

(b) Assuming that $1\,\text{u} = 1.66\times10^{27}\,\text{kg}$ and the radius of a nucleus to be given by $R = r_0 \times A^{1/3}$ ($r_0 = 1.2\,\text{fm}$, A = mass number), calculate the density of nuclear matter. 3

(c) What is the parity of a *p*-electron? Is it same as that of ^{16}O nucleus in its ground state? 2

3. (a) What is Bohr's 'independence hypothesis' for a compound nuclear reaction? 3

(b) What is a resonant reaction? Is it as fast as a direct nuclear reaction? 1+1

(c) Calculate the threshold energy required to initiate the reaction ^{31}P (n, p) ^{31}Si. 3
(Given m_p = 1.00814 u, m_n = 1.00898 u, M_P = 30.98356 u and M_{Si} = 30.98515 u.)

(d) ^{238}U is 'fertile' whereas ^{235}U is 'fissile'– very briefly give the meanings. 2

4. (a) Write down the Bethe-Weizsäcker semi-empirical mass formula of a nucleus, clearly mentioning the meaning of each term. 5

(b) Find the Cerenkov radiation angle for an electron moving with velocity $0.577c$ inside a material of refractive index 2.0. 2

(c) Why is the energy spectrum of α-particles usually mono-energetic whereas β shows a continuous energy spectrum? 3

5. (a) What are "isotopic spin" and "strangeness" of an 'elementary particle'? Are the following reactions possible? Give reasons. 2+2

(i) $n \to p + e^- + \bar{\nu}_e$, (ii) $\pi^+ + n \to p + \pi^-$

(b) A hadron has quark content $u\bar{s}$. Find the baryon number, charge, spin and strangeness of this hadron. 2

(c) The decay $\Sigma^0 \to \Lambda^0 + \gamma$ occurs in nature; whereas the apparently similar decay $\Sigma^+ \to p + \gamma$ never occurs. What is the reason? 2

(d) Identify the type of interaction (strong, weak or electromagnetic) which is responsible for each of the following decays: 2

(i) $\pi^0 \to \gamma + \gamma$ (ii) $K^+ \to \mu^+ + \pi^0 + \nu_\mu$

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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