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The Open University of Sri Lanka
Department of Physics
BSc Degree Programme – Level 5
Final Examination - 2020/2021

Course Code:	**PHU5300**
Course Title:	**Nuclear and Particle Physics**
Date:	**14th March 2022**
Time:	**01:30 pm to 03:30 pm**
Duration:	**2 Hours**

GENERAL INSTRUCTIONS TO CANDIDATES

- Read all instructions carefully before answering the questions.
- Unless specified, standard symbols have their usual meanings.
- This question paper consists of **06 Essay type questions** in 04 pages.
- Answer **only ANY FOUR (04)** questions.
- Non-programmable calculators are allowed.
- Write your answers in the answer book / single sheets provided at the examination hall. Question / section numbers should be written against relevant answers.
- Write your **Index Number** in the spaces provided in the answer book / single sheets.
- Also write all other details requested in the answer book.
- Having any form of unauthorized documents / mobile phones in your possession is a punishable offense.

Answer only ANY FOUR (04) questions.

Useful Physical Constants / Conversions

Mass of $^{235}_{92}U$ in amu = 235.0439

Mass of $^{99}_{40}Zr$ in amu = 98.9165

Mass of $^{134}_{52}Te$ in amu = 133.9115

Mass of n in amu = 1.0089

Avogadro number = 6.022×10^{23} mol^{-1}

1 GW = 1×10^9 J s^{-1}

1 MeV = 1.6022×10^{-13} J

1 amu = 931.5 MeV/c^2

Note: Standard symbols have their usual meanings.

(01) (a) Explain the similarities between a 'liquid drop' and an 'atomic nucleus'.

(b) Based on semi-empirical mass formula, binding energy of a nucleus can be expressed as:

$$E_B(A,Z) = a_V A - a_S A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_{asy} \frac{(A-2Z)^2}{A} \pm \delta(A,Z)$$

Identify each and every term in the above formula.

(c) Describe the contribution of the following terms in the above formula,

i. Surface energy term
ii. Volume energy term
iii. Asymmetric energy term

(02) (a) Derive the exponential law, $N(t) = N_0\, e^{-\lambda t}$, for the decay of radioactive elements. Here, $N(t)$ is the number of radioactive atoms remaining at time, t, N_0, is the number of atoms at $t = 0$, and λ is the radioactive decay constant, which depends on the particular radioactive element.

(b) State the assumptions made in the above derivation.

(c) At present the relative isotopic abundance of U^{235} to U^{238} is 0.0072. Half-lifes of U^{235} and U^{238} are respectively 7.13×10^8 years and 4.51×10^9 years. Assuming that the initial amounts of U^{235} and U^{238} were same at the time of formation of the earth, estimate the age of the earth.

(03) (a) What is "Q value" of a nuclear reaction.

(b) Write down the expression for Q value in the case of a typical α decay. Identify the terms used in your expression.

(c) When a nucleus of mass M_x is bombarded with a particle of mass m_x, the product particle of mass m_y is ejected at an angle of 90° with the direction of bombarding particle.

Show that the Q-value can be expressed as,

$$Q = K_y\left(1 + \frac{m_y}{M_y}\right) - K_x\left(1 - \frac{m_x}{M_x}\right)$$

where, M_y is mass of the product nucleus, K_x is kinetic energy of the nucleus and K_y is kinetic energy of the product nucleus.

(04) (a) Discuss the differences between the nuclear fission and nuclear fusion.

(b) Determine the Q value of the following nuclear fission reaction.

$$^{235}_{92}\mathbf{U} + \mathbf{n} \rightarrow {}^{99}_{40}\mathbf{Zr} + {}^{134}_{52}\mathbf{Te} + 3\mathbf{n}$$

(c) Using the Q value obtained in the above reaction, calculate the amount, in kg, of $^{235}_{92}\mathbf{U}$ required to generate 2 GW power for 30 days.

(05) (a) State four universal conservation laws applicable to all elementary particle reactions.

(b) State any three family conservation laws applicable to all elementary particle reactions.

(c) Determine which conservation law/laws is/are violated in each of the following forbidden reaction.

(i) $\mu^+ \rightarrow e^+ + \nu_e$

(ii) $\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu$

(iii) $n \rightarrow e^+ + e^-$

(iv) $\pi^+ + p \rightarrow \mu^+ + e^+ + \pi^0$

(06) (a) Briefly explain the design and the working principle of a **Cyclotron**, with the help of suitable sketches.

(c) State the significance of the cyclotron frequency.

(b) A cyclotron is used to accelerate a particle with charge q and mass m in a magnetic induction B. Show that the cyclotron frequency, f, can be given by,

$$f = \frac{qB}{2\pi m}$$

(d) State two applications of the cyclotron.

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