The Open University of Sri Lanka
BSc Degree Programme – Level 5
Final Examination - 2023/2024
Nuclear and Particle Physics – PHU5300

-089

Date: 30th March 2024 Time: 01.30 pm – 03.30 pm

Answer Any Four (04) Questions Only

Useful Physical Constants / Conversions

Avogadro number	=	6.022×10^{23} mol^{-1}
1 eV	=	1.6×10^{-19} J
Charge of proton	=	1.6×10^{-19} C
Mass of proton	=	1.67×10^{-27} kg

Note: Standard symbols have their usual meanings.

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

(b) 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. Volume energy term
ii. Surface energy term
iii. Asymmetric energy term

(02) (a) What is "Q value" of a nuclear reaction?

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

(c) Using conservation of momentum and energy, show that the kinetic energy, K_α, of the emitted particle in a α decay process can be given by the equation,

$$K_\alpha = \left(\frac{M_D}{M_\alpha + M_D}\right) Q$$

where, M_α is the mass of the α particle, M_D is the mass of the daughter nucleus and Q is the Q-value of the nuclear reaction. State any assumption that you made in arriving at the above equation.

(03) (a) State the conservation laws applicable to nuclear reactions and briefly describe them.

(b) 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) What is nuclear fusion reaction? Briefly describe the process with a suitable example.

(b) What is nuclear fission reaction? Briefly describe the process with a suitable example.

(c) About 170 MeV of usable energy is released in the neutron induced fission of a $^{235}_{92}U$ nucleus. If $^{235}_{92}U$ in a reactor is continuously generating 100 MW of power, how long will it take for 1 kg of the Uranium to be used up? (State your answer in hours).

(05) (a) Briefly describe the quark concept.

(b) Compare and contrast weak interactions and strong interactions of quarks.

(c) The proton is made up of one *d* quark and two *u* quarks. The neutron is made up of two *d* quarks and one *u* quark. Deduce the charges on the *d* quark and *u* quark.

(06) (a) Explain the principle and working of a *drift-tube linear particle accelerator*, with the help of suitable labelled sketches.

(b) A charged particle of charge q and mass m is to be accelerated through n number of drift tubes with the support of peak potential V_p provided by a RF oscillator having frequency f. Show that the length of n^{th} drift tube can be given by the following equation,

$$l_n = \frac{1}{f}\sqrt{\frac{nqV_p}{2m}} \qquad \left[\text{Note: } l_n = \frac{1}{f}\sqrt{\frac{E_n}{2m}}\text{, where } E_n \text{ is energy gained after } n^{th} \text{ tube}\right]$$

(c) A linear accelerator accelerates a beam of protons from 10 MeV to 127.43 MeV through 10 successive drift tubes. If the frequency of the RF oscillator is 1 MHz, calculate the following quantities:

(i) The Peak Voltage

(ii) Length of the first drift tube

(iii) Length of the last drift tube

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