63/1(SEM–5) DSE2/PHYHE5026

2024

PHYSICS

Paper : PHYHE5026

(Nuclear and Particle Physics)

Full Marks : 80

Pass Marks : 32

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Choose the correct option from the following: ***(any six)*** 1×6=6

   a) In the Bethe-Weizäcker semi-empirical mass formula, the Coulomb repulsion term is

   (i) A

   (ii) $A^{2/3}$

   (iii) $Z(Z-1)A^{-1/3}$

   (iv) $(N-Z)^2A^{-1}$

Contd.

b) To accelerate electrons a Van de Graaff generator uses

(i) electromagnetic radiation

(ii) magnetic fields

(iii) varying electric fields

(iv) electrostatic energy

c) Photons and gravitons are names associated with a category of particles called

(i) mesons

(ii) bosons

(iii) leptons

(iv) baryons

d) The nucleons inside the nucleus obey

(i) Maxwell-Boltzmann statistics

(ii) Fermi-Dirac statistics

(iii) Bose-Einstein statistics

(iv) None of the above

e) The unit of reaction cross-section is

(i) Barn

(ii) Fermi

(iii) Rutherford

(iv) m^{-1}

f) The minimum energy of photon required to undergo pair production is

(i) 0.511 MeV

(ii) 1.022 MeV

(iii) 2.044 MeV

(iv) 4.088 MeV

g) When ${}^{8}_{3}Li$ decays to ${}^{8}_{4}Be$, it does so by

(i) positron emission

(ii) electron emission

(iii) γ-ray emission

(iv) alpha decay

h) The sum of dead time and recovery time of GM counter is called

(i) sensitive time

(ii) ionizing time

(iii) resolving time

(iv) peak-up time

i) The parity is violated in

(i) all elementary interaction

(ii) strong interactions

(iii) weak interactions

(iv) electromagnetic interactions

j) Nuclear force is

(i) short range and charge dependent

(ii) long range and charge dependent

(iii) long range and charge independent

(iv) short range and charge independent

2. Answer ***any five*** of the following questions : 2×5=10

a) What are magic numbers? Give one example of a doubly magic nucleus. 1+1=2

b) What is the role of electric and magnetic fields in particle accelerator?

c) Explain briefly the principle of scintillation detectors.

d) What are the values of baryon number (B), lepton number (L), strangeness (S) and isospin (I) of proton?

e) What are strange particles? How are the strangeness quantum number, baryon number and the third component os isospin related to charge of an elementary particle? 1+1=2

f) A nucleus emits an α particle followed by two β particles. Show that the final nucleus is an isotope of the original nucleus.

g) Complete the following reaction:

(i) $^{27}_{13}Al + p \rightarrow ? + n$

(ii) $^{7}_{3}Li + p \rightarrow ^{7}_{4}Be + ?$

3. Answer ***any six*** of the following questions : 5×6=30

a) Show that the electric quadrupole moment of a nucleus with single charge is $Q = \frac{1}{2}e(3z^2 - r^2)$, where z and r are position coordinates.

b) (i) Arrange the following elementary particles in different particle families such as leptons, baryons, mesons:

$\Xi^-, \pi^0, \nu_\tau, \Omega^-, e^+, K^+$. 3

(ii) What are the structures of neutron and proton in terms of quarks? 3

c) Calculate the Q-value for the following reaction observed by Cockcroft and Walton :

$$ {}^{1}_{1}H + {}^{7}_{3}Li \rightarrow {}^{4}_{2}He + {}^{4}_{2}He $$

The masses of ${}^{7}_{3}Li, {}^{4}_{2}He$ and the proton are 7.016003 amu, 4.002602 amu and 1.007825 amu respectively. Also find the kinetic energy of the products if the incident protons have energy 600 keV. State whether the reaction is exothermic or endothermic. 2+2+1=5

d) Using the semi empirical mass formula, calculate the atomic number of the most stable nucleus for a given mass number *A*.

e) Why cyclotron is not suitable to accelerate electrons? A fixed frequency cyclotron has an oscillator frequency of 12 MHz and dee radius of 0.55 m is used to accelerate deuterons. Calculate (i) the magnetic flux density needed, and (ii) energy to which deuterons are accelerated. Mass of deuteron $= 3.32 \times 10^{-27}$ *kg*. 2+3=5

f) What are leptons? How many leptons are there? Write their names. 2+1+2=5

g) What is β-decay? Write on three types of β-decay. 2+3=5

h) Write a short notes on Rutherford scattering.

i) Write short note on *any one* of the following :

(i) Cherenkov radiation

(ii) Bremsstrahlung

j) Determine the whether the following reactions are allowed or forbidden on the basis of conservation of charge, lepton number, baryon number and strangeness: $2\frac{1}{2} + 2\frac{1}{2} = 5$

(i) $p + p \rightarrow p + n + \pi^{+}$

(ii) $\Sigma^{-} \rightarrow \pi^{-} + n$

4. Answer ***any two*** of the following question : 10×2=20

(a) (i) Calculate the nuclear radius of Te^{125}, if that of Al^{27} is 3-6 fermi. Show that nuclear density is independent of mass number A and is of the order of $10^{14} gm/cm^{3}$. 2+3=5

(ii) Define binding energy of a nucleus. Draw a curve showing the binding energy per nucleon as a function of mass number of nuclei. How this curve can be used to compare the stability of nucleus ? 1+2+2=5

(b) Write briefly about quark model. Write the charge and quantum numbers associated with each quark. 5+5=10

(c) What are the various types of nuclear reaction ? Discuss conservation laws for nuclear raction. 5+5=10

(d) Derive the Bethe-Bloch formula for the energy loss of a heavy charged particle passing through matter. 10

5. Answer ***any one*** of the following questions : 14×1=14

(a) (i) Give salient features of nuclear shell model and point out its successes and failures. 4+3+3=10

(ii) What are the assumptions made in Fermi gas model ? 4

(b) (i) What do you mean by quenching of a GM counter ? What is its necessity ? 2+2=4

(ii) Describe the construction and working of a semiconductor detector. What are the different types of semiconductor detector available ? What are the advantages of semiconductor detector over gas-filled detectors ? 6+2+2=10

(c) (i) What is alpha disintegration energy ? Calculate the kinetic energy of alpha particle in the following decay :

$Pu^{239} \rightarrow U^{235} + He^{4}$.

Given, the masses of Pu^{239}, U^{235} and He^{4} are respectively 239.052158 *amu*, 235.043925 *amu* and 4.002603 *amu*. 2+3=5

(ii) What is quantum mechanical tunnelling ? How does it help to explain the mechanism of α-decay according to Gamow's theory ? 2+3=5

(iii) What is Geiger-Nuttall law ? What is the importance of the law ? 2+2=4
