2021

(Held in 2022)

PHYSICS

(Honours Elective)

Paper : PHY–HE–5056

(Nuclear and Particle Physics)

Full Marks : 80

Time : Three hours

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

1. Give short answers to the following questions : 1×10=10

   (a) The radius of $^{64}_{29}Cu$ nucleus is measured to be 4.8×10^{-13} *cm.* What would be the radius of $^{27}_{12}Mg$?

   (b) Why does neutron number exceed proton number in heavy and intermediate nuclei ?

Contd.

(c) How is the deviation of the charge distribution of a nucleus from spherical symmetry measured ?

(d) What is the parity of the function $\psi(x) = \cos(\pi x/a)$?

(e) What is the relation between the range of alpha particle and decay constant of the emitting nucleus ?

(f) Will there be any difference between the energy spectra of electrons and positrons in β-decay ?

(g) Can a photon of energy 1 *MeV* undergo pair production ?

(h) The maximum energy of deuterons coming out of a cyclotron is 20 *MeV*. What will be the maximum energy of protons that can be obtained from this accelerator ?

(i) What property distinguishes neutrino from anti-neutrino ?

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

2. Briefly answer the following questions : 2×5=10

(a) What is the distance of closest approach of an α-particle of energy 5 *MeV* when it is scattered by an angle 180° by a fixed uranium nucleus ?

[Given $\varepsilon_0 = 8.85\times10^{-12}\,F/m$, $e = 1.6\times10^{-19}\,C$]

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

(c) Show that the mean momentum of a nucleon in a nucleus with mass number A varies as $A^{-1/3}$.

(d) What is straggling of range ?

(e) Show that pion decay, muon decay and pair production conserve the lepton number.

3. Answer ***any four*** of the following : 5×4=20

(a) What are mass defect and packing fraction ? The mass of deuteron is 2.014103 amu. If the masses of proton and neutron are respectively 1.007825 amu and 1.008663 amu, find the mass defect and packing fraction of deuteron.

(b) How can it be shown that nuclear forces are of short range ?

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

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

[Given, $M(Pu^{239}) = 239.052158$ amu,

$M(U^{235}) = 235.043925$ amu,

$M(He^{4}) = 4.002603$ amu]

(d) Show that the frequency of revolution of the ion in a cyclotron is independent of its speed and the radius of the path. Can electron be accelerated in a cyclotron ?

(e) How can neutron be detected ?

(f) What are 'strange' particles ? How are the strangeness quantum number, the baryon number and the third component of isotopic spin related to the charge of the elementary particle ?

4. Answer the following questions : 10×4=40

(a) (i) What are the characterisitics of nuclear force ?

(ii) Explain meson field theory put forward by Yukawa to explain nuclear force. 5+5=10

Or

(i) Write the semiempirical mass formula.

(ii) Explain the significance of various terms. 2+8=10

(b) (i) How is the energy spectrum of alpha particles different from that of beta particles ?

(ii) What difficulties are faced in explaining beta spectrum without neutrino hypothesis ?

(iii) How does neutrino hypothesis help in solving beta spectrum ?

(iv) A free neutron decays into a proton, an electron and an antineutrino. If $M(n) = 1.00898\ u$, $M(p) = 1.00759\ u$ and $M(e) = 0.00055\ u$, find the kinetic energy (in MeV) shared by the electron and the antineutrino. 1+4+2+3=10

Or

(i) Describe how γ-rays interact with matter.

(ii) How does the relative importance of each process depend on energy of gamma radiation ?

(iii) A beam of monoenergetic γ-rays is incident on an aluminum sheet of thickness 10 *cm*. The sheet reduces the intensity of the beam to 21% of the original. Calculate the linear and mass absorption coefficients, given density of aluminum is 2700 $kg.m^{-3}$. 5+2+3=10

(c) (i) What is the Q-value of a nuclear reaction ?

(ii) What are the conservation laws applicable to a nuclear reaction ?

(iii) Find an expression of threshold energy for the nuclear reaction.

(iv) Calculate the threshold energy for the nuclear reaction $^{14}N(n,\alpha)^{11}B$ in *MeV*. [Given
$M(^{14}N) = 14.007550\ u$,
$M(^{11}B) = 11.012811\ u$,
$M(n) = 1.008987\ u$ and
$M(\alpha) = 4.003879\ u$]
1+3+3+3=10

Or

(i) What is meant by cross-section of a nuclear reaction ?

(ii) What are differential cross-section and total cross-section ?

(iii) What is the difference between compound nucleus reaction and direct reaction ? Give *one* example in each case. 4+3+3=10

(d) (i) Describe the construction and working principle of a linear accelerator.

(ii) Electrons are accelerated to 30 *GeV* in the SLAC linear accelerator. Calculate the difference between the electron's speed and the speed of light. 7+3=10

Or

Write short notes on ***any two*** of the following : 5×2=10

(i) K-electron capture

(ii) Cherenkov radiation

(iii) Quark model
