Total number of printed pages–7

63/2 (SEM–4) PHY 403

2024

PHYSICS

Paper : PHY 403

(Advanced Nuclear Physics–II)

Full Marks : 80

Pass Marks : 32

Time : Three hours

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

1. Answer the following questions : ***(any five)*** 1×5=5

   (a) Which of the following transitions typically has the highest probability of occurrence in gamma-ray emission ?

   (i) El transition

   (ii) Ml transition

   (iii) E2 transition

   (iv) M2 transition

Contd.

(b) Which of the following factors can influence the position of a peak in a Mossbauer spectrum ?

(i) Chemical state of the absorbing atom

(ii) Temperature of the source

(iii) Intensity of the gamma ray source

(iv) Distance between source and absorber

(c) The mass distribution of fission products is

(i) Symmetric, with *two* equal-sized fragments

(ii) Asymmetric, with a wide range of fragment masses

(iii) All fragments have the same atomic number

(iv) All fragments are stable isotopes

(d) Nuclear reaction rate in the Sun is

(i) Predominantly governed by CNO cycle

(ii) Predominantly governed by P-P cycle

(iii) Governed by P-P and CNO cycles equally

(iv) More predominantly by P-P than CNO cycle.

(e) The discovery of neutrino oscillation implies that

(i) Neutrinos have no mass

(ii) Neutrinos have a definite flavour

(iii) Neutrinos have a non-zero mass

(iv) Neutrinos travel faster than light

(f) The radiation weighting factor depends

(i) Only on the energy of the radiation

(ii) Only on the particle type of radiation

(iii) Both the energy and particle type of radiation

(iv) None of the above

2. Answer ***any five*** of the following questions : $2 \times 5 = 10$

(a) Write down the Angular momentum and Parity selection rules for gamma transition. Why gamma transition is not allowed when the initial and final state spins of the excited nucleus are both zero ?

(b) A thermal reactor uses enriched uranium-235 fuel $(\eta \approx 2{\cdot}05)$. The reactor core has a thermal neutron utilization factor (f) of 0·82 and a resonance escape probability (p) of 0·90. The fast fission factor (ε) is estimated to be 1·03. Calculate the critical multiplication factor (k_{eff}) needed for this reactor to operate at a steady state. Write whether the reactor is operating in sub-critical, critical or super-critical condition.

(c) Using Lawson criteria calculate the confinement time for deuterium-tritium fusion with the parameters :

$Q = 17{\cdot}62 MeV$. $(\sigma_{id}.v) = 10^{-22} m^3 s^{-1}$.

Deuterium/tritium density = $7 \times 10^{18} m^{-3}$ and $KT = 100 keV$.

(d) During the year a worker receives $10mGy$ from internally deposited alpha particles in stomach, $200mGy$ from beta particle in the liver and $15mGy$ externally from uniform whole body gamma radiation. What is the effective dose for this worker ?

(e) The dose rate at $2m$ from a particular gamma source is 400 Sv/hr. At what distance will it give a dose rate of 25 Sv/hr?

(f) Briefly describe *two* different types of detectors used in neutrino oscillation experiments. Give an example of a specific experiment that utilizes each type of detector.

3. Answer ***any five*** of the following questions : 5×5=25

(a) Classify neutrons on the basis of energy.

(b) Mention *any two* characteristics of an ideal moderator. Why the mean logarithmic decrement in energy (ξ) is considered to be a partial measure of moderating ability of a moderator ? Define mod-erating ratio. Give *two* examples of good moderating material. 2+1+1+1=5

(c) Why neutrons are emitted during fission reaction ? What are the *prompt* and *delayed* neutrons? Discuss the experiment that lead to the discovery of delayed neutrons. 1+1+1+2

(d) What is S-process and R-process in nuclear synthesis ? Show with some examples of R and S processes in synthesis of element A (mass number) > 56.

(e) Derive the Fermi age equation for neutrons in a nuclear fission reactor.

(f) Describe the solar and atmospheric neutrino anomaly.

4. Answer ***any four*** of the following questions : 10×4=40

(a) Show that the mean fractional energy loss per collision for a neutron while slowing down in a mod-erating assembly is independent of the initial energy. Why it is convenient to adopt the logarithm of energy as the variable, rather than the energy itself. Derive an expression for the mean logarithmic decrement in energy. 5+1+4=10

(b) What is fission chain reaction ? Define *multiplication factor* for chain reaction. Derive the *four factor formula* for a fission reactor of infinite size. Describe the modifications required in *the four factor formula* to account for finite size effects. 1+1+7+1=10

(c) Discuss the nucleosynthesis mechanisms of proton-proton (P-P) cycles and CNO cycle for synthesis of element up to ^{56}Fe.

(d) Explain why tritium and deuterium $(T+D)$ reaction is particularly considered suitable for nuclear fusion machines. Discuss the requirements for sustained controlled nuclear fusion. Also discuss different confinement schemes used to reach the sustained nuclear fusion.

(e) (i) Discuss three strategies that can be opted to reduce the effect of different types of radiations. Discuss the challenges associated with effectively shielding neutrons and explore potential solutions to overcome these obstacles. 3+3=6

(ii) Define Half Value Layer (HVL). The dose rate close to a valve is 160 $\mu Sv/hr$. If this is due to cobalt-60 inside the valve, how much lead shielding must be placed around the valve to reduce the dose rate to 10 $\mu Sv/hr$? HVL of lead for gamma radiation is 12mm. 1+3=4

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