Ref. No. : Ex/PE/PC/B/T/322/2023

B.E. POWER ENGINEERING THIRD YEAR
SECOND SEMESTER
EXAM – 2023
NUCLEAR POWER GENERATION

Time : 3 hours | Full Marks : 100

All Sections (A, B & C) are compulsory.

m_e	=	$0.0005486\ (u)$	R_0	=	$1.2\ fm$
m_p	=	$1.007825\ (u)$	$1\ u$	=	$931.5\ {}^{MeV}/_{c^2}$
m_n	=	$1.008665(u)$	N_A	=	6.022×10^{23}

k : *Boltzman Constant*

$= 1.3806 \times 10^{-23}\ \frac{Joule}{keV}; = 8.6 \times 10^{-5}\ \frac{eV}{K};$

Section A

All questions are compulsory and carry 3 marks each.

1	Neutrons are classified based on their energies. What is the typical energy for thermal, epithermal and fast neutrons, what can you predict about the approximate wavelength of these three categories.
2	What do you understand by the term "rest mass" of an sub-atomic particle. What is the rest mass energy for an electron ($m_e = 9 \times 10^{-31}\ kg$) in eV.
3	Prove that the Roentgen represents the energy absorption which corresponds to $83.8\ \frac{ergs}{gm}$ of air
4	What is the most important property for a material to be used as a "control rod" as well as a "moderator
5	Define "microscopic cross section" and how is it related to "macroscopic cross section".
6	18 grams of water contain how many moles and molecules.
7	What do you comprehend by "Loss of Coolant" accidents
8	Name the three nuclear reactor accidents till date.
9	What is "average logarithmic energy decrement".
10	We have 100 number of radioactive atoms, whose half-life is 2 days. How many atoms are present after 2 half lives.

Section B

Attempt any 5 questions each carry 6 marks.

1	Given the reactions $H^2 + H^3 \longrightarrow He^4 + n\ \&$ $n + U^{235} \longrightarrow X^{97} + Y^{137} + 2n$ $m_{H2} = 2.014102\ (u);\ m_{H3} = 3.016049\ (u)\ ;\ m_{He} = 4.002602\ (u)$ $m_{U235} = 235.043924\ (u);\ m_X = 96.92120\ (u)\ ;\ m_Y = 136.9060\ (u)$ Which of the two reactions produces more energy.
2	Compute the ratio of the nuclear density for $^{12}C(Z=6)$ and $^{208}Pb(Z=82)$ nuclei.
3a	Given the observations that the elastic scattering cross section is directly proportional to the surface area of the nucleus *viz.* $\sigma = 4\pi R^2\ \&\ R = R_0 A^{1/3}$ Sketch the plot of $\frac{\sigma}{2\sqrt{\pi}}$ and $A^{1/3}$ with $A^{1/3}$ along the x-axis. How would you deduce the value of R_0 from this plot.

[Turn over

3b Suppose a quantity B_v is directly proportional to the volume of the nucleus, (the nucleus is spherical in shape), deduce a relationship between B_v and A. Sketch the plot of $\frac{B_v}{A}$ (y-axis) and A.

4 From the data given below prove that ^{235}U would undergo fission under the absorption of a thermal neutron, whereas ^{238}U would not.

$$m_{235U} = 235.04393\ (u);\ m_{236U} = 236.04556\ (u)$$
$$m_{238U} = 238.05071\ (u)\ ;\ m_{239U} = 239.0543\ (u)$$
$$E_{critical}^{235U} = 6.4\ MeV\ \&\ E_{critical}^{238U} = 7.0\ MeV$$

5 Using the data in the following table compute the atomic weight of naturally occurring oxygen.

Isotope	Abundance (%)	Atomic weight
^{16}O	99.759	15.99492
^{17}O	0.037	16.99913
^{18}O	0.204	17.99916

6 How much energy would be required to assemble U_{92}^{238} nucleus, given $m_U = 238.05078826\,u$ for individual and independent components. From this information compute the Packing fraction for this nucleus.

7 The microscopic cross section of Cu is 3.85 barns. Density of Copper is 8940 kg-m3. Atomic weight of copper is 63.55 gm/mole. Calculate the macroscopic absorption cross section and the mean free path of the neutron.

Section C

Attempt any **four** questions. All questions carry 10 marks each.
Attempt all sub-sections within one question.

1 a) What is the conventional unit used to describe the mass of sub-atomic particle. Prove that one such unit is equal to the reciprocal of Avogadro's Number (N_A). 4

b) Define Binding Energy. Plot the B.E per nucleon as a function of the nucleon number and use this to explain the observation that fission is energetically favourable. 6

2 a) What is Reactivity. What are units used to quantify "reactivity". Explain the significance of delayed neutrons in controlling the reactivity of the reactor. 6

b) What do you understand by the term "neutron poison". 4

3 a) What are the different mechanizms with which a neutron undergoes interaction with matter. Prove mathematically that a light material is a better moderator than a heavier element. 10

4 a) For a successive disintegration show that 10

$$N_2 = \frac{N_0 * \lambda_1}{\lambda_2 - \lambda_1}\left\{e^{-\lambda_1 t} - e^{-\lambda_2 t}\right\}$$

Where the symbols have their usual meaning. Define the unit of activity.

5 a) Describe briefly the general components of a nuclear reactor, with a suitable diagram. 4

b) What do you comprehend by the term "fission" for a heavy nucleus and how does it explain the working of a nuclear reactor. What is the energy released in fission of one heavy nucleus. 6

6 What do you comprehend by the term "chain reaction" and "criticality of a reactor". Describe in detail the components which constitute the formula describing the multiplication factor for an infinite reactor. How does one modify the same to describe the multiplication factor for a real / practical reactor. 10

7 a) Why does a light water reactor have to be operated at high pressure ? Why should the fuel used in there be enriched ? What is the advantage of Heavy Water Moderated Reactor ? 5

b) Using the data in the following table compute the atomic weight of naturally occurring Uranium. 5

Isotope	Abundance (%)	Atomic weight
^{234}U	0.0054	234.040 9523
^{235}U	0.7204	235.043 9301
^{238}U	99.2742	238.050 7884

8 Explain the principle and operation of a Fast Breeder Reactor. Describe briefly the desirable and undesirable characteristics of Liquid Na as a coolant. Enumerate the need for two Na loops and sketch either the Loop Design or the Pool Design for LMFBR. Define the Conversion ratio and state the condition for breeding. 10