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

B.E. POWER ENGINEERING THIRD YEAR
SECOND SEMESTER
SUPPLEMENTARY 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	=	$1.008665(u)\ ;\ 1.675 \times 10^{-27}\ kg$	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	What unit of "energy" is used in Reactor Physics. Define the unit and state it's relation with the conventional unit of energy.
2	What do you understand by the term "rest mass" of a sub-atomic particle. What is the rest mass energy for an electron ($m_n = 1.674927471 \times 10^{-27}\ kg$) in eV.
3	The atomic weight of Cu^{63} is 62.9296 *amu*. How much heavy is Cu^{63} as compared to C^{12}.
4	What is the most important property for a material to be used as a "control rod" as well as a "moderator
5	Define the term "atom density". Define "microscopic cross section" and how is it related to "macroscopic cross section".
6	How many particle (atoms or molecules) are present in 1 mole of a substance. How many atoms are there in 10 grams of C^{12}.
7	A thermal neutron ($v \sim 1515\ m/s$) crosses the ${}^{235}_{92}U$ nucleus. How much time would it take to cross this nucleus.
8	Name the three nuclear reactor accidents till date.
9	Given $R_{atom} = 10^{-10}\ m$ & $R_{nuclear} = 10^{-15}\ m$, prove that there is considerable space within the atom.
10	We have 100 number of radioactive atoms, whose half-life is 2 days. How many atoms are present after 8 days.

Section B

Attempt any 5 questions each carry 6 marks. If a question contains sub-questions attempt all the sub-questions.

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.
2a	Prove that the nuclear density is identical for all nuclei.

2b If earth were to have the same density as that of the nucleus, and it's mass is $6 \times 10^{24}\ kg$, then compute the radius of the earth.

3a Where the symbols have their usual meaning, given the relation

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

At $v \ll c$, obtain the expression for the Kinetic Energy of the system.

3b Using the above expression for the mass, prove that

$$p = \frac{1}{c}\sqrt{E_{total}^2 - E_{rest}^2}$$

4a Fission of a single atom of U_{92}^{235} releases about 200 MeV of energy. How much energy is released when 10 grams of U_{92}^{235} undergo fission.

4b Ra^{226} decay occurs following an alpha emission, with half-life of 1600 years. What is the activity of 2 grams of this material and how many alpha particles would we observe in one second.

5 a Compare the wavelength of a thermal neutron and a neutron whose kinetic energy is 1 MeV.

5b Compute the mass difference between the neutron and proton in terms of MeV.

6 How much energy would be required to assemble Pb_{82}^{206} nucleus, given $m_{Pb} = 207.97665\ u$ 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/m^3. 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)	Define 1 atomic mass unit. Prove that one such unit is equal to the reciprocal of Avogadro's Number (N_A). What is the energy equivalent of 1 amu.	4
	b)	Define Mass Defect and Binding Energy. Plot the B.E per nucleon as a function of the nucleon number and use this to explain the observation that fission in heavier nuclei and fusion in lighter nuclei is energetically favourable.	6
2		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
3		What are the different mechanisms with which a neutron undergoes interaction with matter. Prove mathematically that a light material is a better moderator than a heavier element. Can you qualitatively establish the $\frac{1}{E}$ dependence of the reaction cross section for neutrons.	10
4	a)	State the law of radioactive decay and obtain an expression for the number of surviving atoms at a given point of time. Prove that after 5 half lives the activity of the sample tends to zero. Prove that only at $t = \infty$, would all the atoms of the radioactive material decayed	5
	b)	With the help of a sketch describe the major components of a nuclear reactor.	5

5	a)	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	7
	b)	Of the isotopes of U, only U^{235} has a substantial cross section for fission $\sigma_{fis} = 580\ b$, but it's natural abundance is only 0.7%. Now following the enrichment of U^{235} to 3% show that there would be a substantial increase in the fission probability.	3
6	a)	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.	7
	b)	A reactor is operating at a flux level of $3 \times 10^3\ neutrons/cm^2 - sec$ and contain approximately Avogadro number of atoms of U^{235} per cc. If the reaction rate is $1.29 \times 10^{12}\ fission/cc$, compute the Σ_f & σ_f	3
7	a)	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

7	b)	What is the atom density of ^{235}U enriched to 2.5 a/o in this isotope if the density of U is 19.0 gm/cc and use the results of above question.	5
8	a	Define Roentgen and RAD. Prove that 1 R quantity of radiation is that quantity of radiation in which 83.8 ergs are absorbed per gram of air.	6
	b	Define the terms "neutron flux", "rate of neutron interaction" and "reactor period". How is the neutron density related to the power of the reactor. Bring out the significance of delayed neutrons in reactor control.	4