Ref: EX/PE/PC/B/T/322

BACHELOR OF POWER ENGINEERING EXAMINATION, 2022, 3rd year 2nd sem
NUCLEAR POWER GENERATION

Time : 3 hours **Full Marks : 100**

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

	m_e	=	0.0005486 (u)
	m_p	=	1.007825 (u)
	m_n	=	1.008665(u)
	k	:	*Boltzman Constant* $= 1.3806 \times 10^{-23}$ *Joule/keV*
	R_0	=	$1.2\ fm$
	$1\,u$	=	$931.5\ {}^{MeV}/_{c^2}$
	N_A	=	6.022×10^{23}

Section A

All questions are compulsory and carry 3 marks each.

1	Define **rest mass energy**. What is the rest mass energy for an electron ($m_e = 9 \times 10^{-31}\ kg$) in eV.
2	What do you understand by the term "reactor poison". Explain briefly the effect of Xe^{135} has on reactivity and how is it addressed.
3	What do you understand by "slow" and "fast" neutrons. What is the typical velocity of a slow neutron.
4	What is the need for reactor control system. What do you understand by the term "chemical shimming".
5	How does one quantify the effectiveness of a control rod. State the parameters which govern the effectiveness of control rod.
6	Why are reflectors used in reactors. What are the desirable properties of the reflector.
7	What is the need for fuel enrichment. Name the methods followed for enrichment of Uranium.
8	Why cannot steel be used as a reactor material. Which is the preferred material for use in reactor and why.
9	Elastic cross section of U^{238} is 9.3 barns upto 10 eV. From this data compute the radius of this nucleus..
10	What is "absorbed dose". What is it's S.I unit and how is it defined.

Section B

Attempt any **five** questions each carry 6 marks.
Attempt all sub-sections within one question

1		Which of the following reactions are energetically favourable $^{232}_{92}U \rightarrow {}^{228}_{90}Th + \alpha$ $^{232}_{92}U \rightarrow {}^{231}_{91}Pa + p$ $m_U = 232.03713\ (u);\ m_{Th} = 228.0287\ (u)\ ;\ m_{Pa} = 231.0358\ (u)\ ;\ m_\alpha = 4.0026\ (u)$	6
2	a)	Calculate the radius and nuclear density for Sn^{122}. Using the information on the nuclear density for this nucleus predict the nuclear density for Pb^{208} nucleus.	5
	b)	Why do certain terms in the liquid drop model have a negative sign to the coefficients.	1
3	a)	From the given the following data calculate the mean path for a neutron in water $\rho_{H_2O} = 1000\frac{kg}{m^3};\ \sigma_H = 0.33\,b\ ;\ \sigma_O = 2 \times 10^{-4}\,b\ ;\ 1b = 10^{-28}m^2$	3

b) Compute the wavelength of 1 MeV photon. Compare it with the wavelength of 1 MeV neutron, given that $m_n = 1.67 \times 10^{-27} kg$. 3

4 a) Calculate the macroscopic cross section for U, from the following data, where the terms have their usual significance.

$$\rho_U = 19.0 \times 10^3 \frac{kg}{m^3};$$
$$\sigma_{238U} = 2.7\ b\ ;\ \%\ abundance\ is\ 99.28$$
$$;\sigma_{235U} = 681\ b\ ;\ \%\ abundance = 0.72$$

b) Neutron cross-section(s) exhibit an inverse dependence on the neutron velocity. Explain why. 2

5 Using the data in the following table compute the molecular weight of H_2, H_2O & H_2O_2 8

Isotope	Abundance (%)	Atomic weight (u)
^{1}H	99.985	1.007825
^{2}H	0.015	2.01410
^{16}O	99.759	15.99492
^{17}O	0.037	16.99913
^{18}O	0.204	17.99916

6 a) In a reactor environment we have typical energies of gamma rays up to 10MeV. For these photons we have the mass absorption co-efficient as $\mu_m = 0.05\ ^{sq\ cm}/_{gm}$. What thickness of lead is required to reduce the photon intensity by a factor of 10^{-10} 3

b) If the gain in the binding energy during the fission process is typically 1 MeV/A, then how much energy is released if 1 gram of a fissile nucleus (A = 240) undergoes fission. 3

7 a) Prove that 1 a.m.u is numerically equal to the reciprocal of Avagrado Number (N_A) 2

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

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

Section C

Attempt any **five** questions. All questions carry 8 marks each.
Attempt all sub-sections within one question.

1 a) Define mass defect and Binding Energy for a nucleus. 2
b) 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. 4
c) Why are heavy nuclei (A > 240) less stable. 2

2 a) State the Law of Radioactive decay. What do you understand by the term "equilibrium" 2
b) For a successive disintegration show that 4

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

Where the terms have their usual meaning.
c) What do you understand by the term "attenuation of gamma rays". Write down the relevant equation and state the various terms in the equation. 2

3 a) Define "fission". 2
b) How is fission explained on the basis of the liquid drop model. 4

	c)	The radiative capture and fission cross section for U are 99 b and 582 b respectively. What is the relative probability that fission would occur.	2
4	a)	What do you comprehend by the terms "elastic" and "inelastic scattering" of neutrons.	3
	b)	Prove (using the appropriate equation(s)) that lighter materials are efficient moderators. What are the desirable properties of a moderator.	5
5	a)	With a suitable block diagram explain briefly the main components of a nuclear reactor.	6
	b)	Name the three nuclear reactor accidents that have occurred till date.	2
6	a)	What are the main differences between a light water and a pressurized heavy water reactor. Explain the features of large pressure vessel tube known as "Calandria".	5
	b)	A reactor is cubic in shape whose sides are 0.5m long. The typical neutron flux is $10^{14}\ {}^{neutrons}/_{sq.cm-second}$. If the probability of fission per unit length is 0.1 cm^{-1}, calculate the power of the reactor.	3
7	a)	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
	b)	Define the term "neutron multiplication factor", denoted by K. What is the main difference between the four factor and six factor formula for K. Explain briefly the "thermal utilization factor"	4
8	a)	Define microscopic and macroscopic cross section for neutrons.	3
	b)	Define "Roentgen", and prove that the Roentgen represents the energy absorption which corresponds to 83.8 $\frac{ergs}{gm}$ of air.	5