國立清華大學 107 學年度碩士班考試入學試題

系所班組別：核子工程與科學研究所 甲組(工程組)

考試科目（代碼）：核工原理(3002)

 *請在【答案卷】作答

1. (20%, each 5%) Briefly explain the following terms:
   A. Cross sections and stopping powers
   B. Nuclear stability and radioactive decay
   C. Delay neutrons and reactor control
   D. Boiling water reactors and pressurized water reactors

2. (20%) Consider two homogenous regions in a reactor: (1) an aluminium fuel rod follower having a density of 2.69 g/cm^3 and a diameter of 1.2 cm, (2) a boron-carbide (B_4C) plate having a density of 2.65 g/cm^3 and a thickness of 0.2 cm. From the point of view of a thermal neutron, determine whther the two regions are "large" or "small" in terms of a transport mean free path? The transport cross section is given by

$$\Sigma_{tr} = \Sigma_a + \Sigma_s(1-\bar{\mu}) \approx \Sigma_a + \Sigma_s\left(1-\frac{2}{3A}\right)$$

3. (20%) Consider a critical system consisting of an infinite bare slab of thickness a and assume the extrapolation distrance d that the flux vanishes beyond the surface is small compared to a. The reactor power is P and the recoverable energy per fission is E_R, based on the one-group reactor equation, please derive the following expression for the approximate thermal flux distribution in the slab reactor.

$$\phi(x) = \frac{\pi P}{2aE_R\Sigma_f}\cos(\frac{\pi x}{a})$$

4. (20%) Consider a homogenous mixture of U-235 and iron in which the uranium is 1 wt% (weight percent) of the total. (1) What is the value for the fuel utilization f and the infinite multiplication factor k_∞ ? (2) What is the critical weight percent of the uranium in the mixture?

5. (20%) Rn-222 is a radioactive gas belonging to the radium and U-238 decay chain, and has a half-life of 3.8 days. Assume ^{222}Rn is seeping into a basement (no ventilation) at a rate of 6.6×10^{10} atoms/s. The basement has a volume of 125 m^3. What will the asymptoic concentration of Rn-222 and its activity?

Appendix:

TABLE II.3 PROPERTIES OF THE ELEMENTS AND CERTAIN MOLECULES

Element or Molecule	Symbol	Atomic Number	Atomic or Molecular Weight*	Nominal Density, g/cm³	Atoms or Molecules per cm³† (×10²⁴)	σ_a,‡barns	σ_s,‡ barns	Σ_a,†cm⁻¹	Σ_s,‡ cm⁻¹
Actinium	Ac	89	227			515			
Aluminum	Al	13	26.9815	2.699	0.06024	0.230	1.49	0.01386	0.08976
Antimony	Sb	51	121.75	6.62	0.03275	5.4	4.2	0.1769	0.1376
Argon	Ar	18	39.948	Gas		0.678	0.644		
Arsenic	As	33	74.9216	5.73	0.04606	4.3	7	0.1981	0.3224
Barium	Ba	56	137.34	3.5	0.01535	1.2		0.01842	
Beryllium	Be	4	9.0122	1.85	0.1236	0.0092	6.14	0.001137	0.7589
Bismuth	Bi	83	208.980	9.80	0.02824	0.033		0.0009319	
Boron	B	5	10.811	2.3	0.1281	759	3.6	97.23	0.4612
Bromine	Br	35	79.909	3.12	0.02351	6.8	6.1	0.1599	0.1434
Cadmium	Cd	48	112.40	8.65	0.04635	2450	5.6	113.56	0.2596
Calcium	Ca	20	40.08	1.55	0.02329	0.43		0.01001	
Carbon (graphite)	C	6	12.01115	1.60	0.08023	0.0034	4.75	0.0002728	0.3811
Cerium	Ce	58	140.12	6.78	0.02914	0.63	4.7	0.01836	0.1370
Cesium	Cs	55	132.905	1.9	0.008610	29.0		0.2497	
Chlorine	Cl	17	35.453	Gas		33.2			
Chromium	Cr	24	51.996	7.19	0.08328	3.1	3.8	0.2582	0.3165
Cobalt	Co	27	58.9332	8.8	0.08993	37.2	6.7	3.345	0.6025
Copper	Cu	29	63.54	8.96	0.08493	3.79	7.9	0.3219	0.6709
Deuterium	D	1	2.01410	Gas		0.00053			
Dysprosium	Dy	66	162.50	8.56	0.03172	930	100	29.50	3.172
Erbium	Er	68	167.26	9.16	0.03203	162	11.0	5.189	0.3523
Europium	Eu	63	151.96	5.22	0.02069	4600	8.0	95.17	0.1655
Fluorine	F	9	18.9984	Gas		0.0095	4.0		

TABLE 6.1 NOMINAL ONE-GROUP CONSTANTS FOR A FAST REACTOR*

Element or Isotope	σ_γ	σ_f	σ_a	σ_{tr}	ν	η
Na	0.0008	0	0.0008	3.3		
Al	0.002	0	0.002	3.1		
Fe	0.006	0	0.006	2.7	—	—
^{235}U	0.25	1.4	1.65	6.8	2.6	2.2
^{238}U	0.16	0.095	0.255	6.9	2.6	0.97
^{239}P	0.26	1.85	2.11	6.8	2.98	2.61

*From *Reactor Physics Constants*, 2nd ed., Argonne National Laboratory report ANL-5800, 1963.