1. 10%; [(a) 4%, (b) 6%]

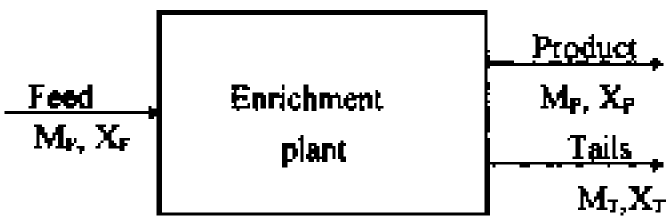
(a) All nuclei scatter neutrons, what distinguishes an elastic scatter and an inelastic scatter?

(b) Calculate the microscopic one-group thermal absorption cross-section of ^{135}Xe at 100°C using the following data:

non-1/v factor $g_a(100^{\circ}C) = 1.21$,

$\sigma_a(20^{\circ}C) = 2.65 \times 10^6$ barn.

2. 10%; (5% each)



M : weight of uranium

x : weight fraction in ^{235}U

(a) $M_P = f(x_P, x_F, x_T)\, M_F$. Use material balance equations to determine $f(x_P, x_F, x_T)$, which is a function of ^{235}U fractions in product, feed and tails.

(b) Suppose for each ^{235}U weight fraction x, we know its value function V(x). Define the separative work unit.

3. 20%; [(a),(b) 6% each, (c)8%]

A spherical reactor core (radius R) is surrounded by reflector (thickness T).

(a) Use one-group theory, write down the reactor equation in the core and the diffusion equation in the reflector.

(b) What are the boundary conditions that must be satisfied by ϕ_c and ϕ_r.

(c) Derive the critical condition for this reflected spherical reactor.

4. 10%; [(a) 4%, (b) 6%]

Tritium (^3H) decays by negative beta decay with a half-life of 12.3 years. The average energy of beta is 6 keV.

(a) To what nucleus does ^3H decay?

(b) ^3H has a biological half-life of 12 days, how long is its effective half-life?

5. Please show that the relation between exposure rate ($\dot{X}$, Roentgen/sec) and absorbed dose rate ($\dot{D}$, Rad/sec) can be expressed as $\dot{D} = f\,\dot{X}$.

Hint: 1 Roentgen is equivalent to the production of 1 esu (3.33×10^{-10} coul) of charge from the interaction of gamma radiation in 0.001293 g of air; 1 electronic charge is 1.60×10^{-19} coul and 34 eV of energy is required to create an ion pair; also 1 MeV $=1.6\times10^{-6}$ erg.

1 Rad is equal to the absorption of 100 erg of energy per gram of tissue. You need to define the notations used in the derivation. *(5%)*

6. There are two fundamental mechanisms by which radiation can affect an cell. These are direct effect and indirect effect. Please explain how the damage to the cell is caused in these two mechanisms. Between these two mechanisms, which one is more important in producing biological effect, Why? *(4%)* The biological effects of radiation are usually divided into two broad classes, e.g. stochastic and nonstochastic effects. Please explain what are the stochastic and the nonstochastic effects. *(4%)*. Please explain the term "linear hypothesis" used in the quantification of biological effect of radiation. Is it used in related to the stochastic or the nonstochastic effect? *(2%)*

7. A isotropic point source of 1-MeV gamma rays of intensity $10^8\ \gamma\ rays/\sec\ cm^2$ is incident upon a spherical lead shield (density is $11.34\ g/cm^3$) 15 cm thick. Calculate at the rear side of the shield: (a) the uncollided flux *(3%)*; (b) the buildup flux *(3%)*, (c) the exposure rate *(2%)*.

Hint: following equation can be used to calculate exposure rate:

$$\dot{X} = 0.0659\, E_0 \left(\mu_a/\rho\right)^{air} \phi_b \quad \left(mR/Hr\right)$$

where $\left(\mu_a/\rho\right)^{air}$ is the mass absorption coefficient of air and ϕ_b is the buildup flux.

8. Describe the nuclear Doppler effect and its impact on the absorption of neutrons when the temperature of fuel increases *(4%)*. Can a thermal reactor operates safely without nuclear Doppler effect? Why? *(3%)*.

9. In the current design of nuclear power plants using light water reactors, the philosophy of "Defense in Depth" is adopted to protect the public and operator. Please describe the details of each item involved in the philosophy *(7%)*.

10. The one-dimensional (r-direction) heat conduction equation of a cylindrical fuel rod is

$$\frac{1}{r}\frac{d}{dr}kr\frac{dT}{dr}+q'''=0$$

Where q''' is power density and k is thermal conductivity. Solve the equation for the fuel matrix with radius a, for the cladding with inner radius a and outer radius b and show that the temperature difference between fuel rod centerline and cladding outer surface can be expressed as:

$$T_m - T_c = q'\left(\frac{1}{4\pi k_f}+\frac{\ln\left(1+\frac{b}{a}\right)}{2\pi k_c}\right)$$

Where q' is linear heat generation rate and k_f, k_c are thermal conductivity of fuel and cladding, respectively *(7%)*.

11. Please write the balance equation of Xe. What are the equilibrium concentration of Xe *(3%)*. Sketch qualitatively the variation of Xe concentration in a transient of step power decrease. Explain your answer *(3%)* (Hint: The neutron absorption cross section of I is very small and can be ignored in the balance equation.)

I → Xe → Cs → Ba (stable)

Use following notations in your equations:

γ_I : fission yield of I;

γ_{Xe} : fission yield of Xe;

Σ_f : fission cross section;

ϕ_T : thermal neutron flux;

λ_I : decay constant of I (half life of I is 6.7 hour);

λ_{Xe} : decay constant of Xe (half life of Xe is 9.2 hour);

$\sigma_{a,Xe}$: absorption cross section of Xe.

八十六學年度 工程與系統科學 系(所) ________ 組碩士班研究生入學考試

科目 核工原理　科號 4002 共 7 頁第 5 頁 *請在試卷【答案卷】內作答

Exposure buildup factor for isotropic point source*

Material	E_0, MeV	μr: 1	2	4	7	10	15	20
Water	0.255	3.09	7.14	23.0	72.9	166	456	982
	0.5	2.52	5.14	14.3	38.8	77.6	178	334
	1.0	2.13	3.71	7.68	16.2	27.1	50.4	82.2
	2.0	1.83	2.77	4.88	8.46	12.4	19.5	27.7
	3.0	1.69	2.42	3.91	6.23	8.63	12.8	17.0
	4.0	1.58	2.17	3.34	5.13	6.94	9.97	12.9
	6.0	1.46	1.91	2.76	3.99	5.18	7.09	8.85
	8.0	1.38	1.74	2.40	3.34	4.25	5.66	6.95
	10.0	1.33	1.63	2.19	2.97	3.72	4.90	5.98
Aluminum	0.5	2.37	4.24	9.47	21.5	38.9	80.8	141
	1.0	2.02	3.31	6.57	13.1	21.2	37.9	58.5
	2.0	1.75	2.61	4.62	8.05	11.9	18.7	26.3
	3.0	1.64	2.32	3.78	6.14	8.65	13.0	17.7
	4.0	1.53	2.08	3.22	5.01	6.88	10.1	13.4
	6.0	1.42	1.85	2.70	4.06	5.49	7.97	10.4
	8.0	1.34	1.68	2.37	3.45	4.58	6.56	8.52
	10.0	1.28	1.55	2.12	3.01	3.96	5.63	7.32
Iron	0.5	1.98	3.09	5.98	11.7	19.2	35.4	55.6
	1.0	1.87	2.89	5.39	10.2	16.2	28.3	42.7
	2.0	1.76	2.43	4.13	7.25	10.9	17.6	25.1
	3.0	1.55	2.15	3.51	5.85	8.51	13.5	19.1
	4.0	1.45	1.94	3.03	4.91	7.11	11.2	16.0
	6.0	1.34	1.72	2.58	4.14	6.02	9.89	14.7
	8.0	1.27	1.60	2.23	3.49	5.07	8.50	13.0
	10.0	1.20	1.42	1.95	2.99	4.35	7.64	12.4
Tin	0.5	1.56	2.08	3.09	4.57	6.04	8.64	
	1.0	1.64	2.30	3.74	6.17	8.85	13.7	18.8
	2.0	1.57	2.17	3.53	5.87	8.53	13.6	19.3
	3.0	1.46	1.96	3.13	5.28	7.91	13.3	20.1
	4.0	1.38	1.81	2.82	4.82	7.41	13.2	21.2
	6.0	1.26	1.57	2.37	4.17	6.94	14.8	29.1
	8.0	1.19	1.42	2.05	3.57	6.19	15.1	34.0
	10.0	1.14	1.31	1.79	2.99	5.21	12.5	33.4
Tungsten	0.5	1.28	1.50	1.84	2.24	2.61	3.12	
	1.0	1.44	1.83	2.57	3.62	4.64	6.25	(7.35)
	2.0	1.42	1.85	2.72	4.09	5.27	8.07	(10.6)
	3.0	1.36	1.74	2.59	4.00	5.92	9.66	14.1
	4.0	1.29	1.62	2.41	4.03	6.27	12.0	20.9
	6.0	1.20	1.43	2.07	3.60	6.29	15.7	36.3
	8.0	1.14	1.32	1.81	3.05	5.40	15.2	41.9
	10.0	1.11	1.25	1.64	2.62	4.65	14.0	39.3
Lead	0.5	1.24	1.42	1.69	2.00	2.27	2.65	(2.73)
	1.0	1.37	1.69	2.26	3.02	3.74	4.81	5.86
	2.0	1.39	1.76	2.51	3.66	4.84	6.87	9.00
	3.0	1.34	1.68	2.43	3.75	5.30	8.44	12.3
	4.0	1.27	1.56	2.25	3.61	5.44	9.80	16.3
	5.1	1.21	1.46	2.08	3.44	5.55	11.7	23.6
	6.0	1.18	1.40	1.97	3.34	5.69	13.8	32.7
	8.0	1.14	1.30	1.74	2.89	5.07	14.1	44.6
	10.0	1.11	1.23	1.58	2.52	4.34	12.5	39.2
Uranium	0.5	1.17	1.30	1.48	1.67	1.85	2.08	
	1.0	1.31	1.56	1.98	2.50	2.97	3.67	
	2.0	1.33	1.64	2.23	3.09	3.95	5.36	(6.48)
	3.0	1.29	1.58	2.21	3.27	4.51	6.97	9.88
	4.0	1.24	1.50	2.09	3.21	4.66	8.01	12.7
	6.0	1.16	1.36	1.85	2.96	4.80	10.8	23.0
	8.0	1.12	1.27	1.66	2.61	4.36	11.2	28.0
	10.0	1.09	1.20	1.51	2.26	3.78	10.5	28.5

八十六學年度 工程與系統科學 系（所）＿＿＿＿組碩士班研究生入學考試

科目 核工原理 科號 4002 共 7 頁第 6 頁 *請在試卷【答案卷】內作答

The mass attenuation coefficient (μ/ρ) for several materials, in cm^2/g*†

Material	Gamma-ray energy, MeV																	
	0.1	0.15	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.25	1.5	2	3	4	5	6	8	10
H	.295	.265	.243	.212	.189	.173	.160	.140	.126	.113	.103	.0876	.0691	.0579	.0502	.0446	.0371	.0321
Be	.132	.119	.109	.0945	.0847	.0773	.0715	.0628	.0565	.0504	.0459	.0394	.0313	.0266	.0234	.0211	.0180	.0161
C	.149	.134	.122	.106	.0953	.0870	.0805	.0707	.0636	.0568	.0518	.0444	.0356	.0304	.0270	.0246	.0213	.0194
N	.150	.134	.123	.106	.0955	.0869	.0805	.0707	.0636	.0568	.0517	.0445	.0357	.0306	.0273	.0249	.0218	.0200
O	.151	.134	.123	.107	.0953	.0870	.0806	.0708	.0636	.0568	.0518	.0445	.0359	.0309	.0276	.0254	.0224	.0206
Na	.151	.130	.118	.102	.0912	.0833	.0770	.0676	.0608	.0546	.0496	.0427	.0348	.0303	.0274	.0254	.0229	.0216
Mg	.160	.135	.122	.106	.0944	.0860	.0795	.0699	.0627	.0560	.0512	.0442	.0360	.0315	.0286	.0266	.0242	.0228
Al	.161	.134	.120	.103	.0922	.0840	.0777	.0683	.0614	.0548	.0500	.0432	.0353	.0310	.0282	.0264	.0241	.0229
Si	.172	.139	.125	.107	.0954	.0869	.0802	.0706	.0635	.0567	.0517	.0447	.0367	.0323	.0296	.0277	.0254	.0243
P	.174	.137	.122	.104	.0928	.0846	.0780	.0685	.0617	.0551	.0502	.0436	.0358	.0316	.0290	.0273	.0252	.0242
S	.188	.144	.127	.108	.0958	.0874	.0806	.0707	.0635	.0568	.0519	.0448	.0371	.0328	.0302	.0284	.0266	.0255
Ar	.188	.136	.117	.0977	.0867	.0790	.0730	.0638	.0573	.0512	.0468	.0407	.0338	.0301	.0279	.0266	.0248	.0241
K	.215	.149	.127	.106	.0938	.0852	.0786	.0689	.0618	.0552	.0505	.0438	.0365	.0327	.0305	.0289	.0274	.0267
Ca	.238	.158	.132	.109	.0965	.0876	.0809	.0708	.0634	.0566	.0518	.0451	.0376	.0338	.0316	.0302	.0285	.0280
Fe	.344	.183	.138	.106	.0919	.0828	.0762	.0664	.0595	.0531	.0485	.0424	.0361	.0330	.0313	.0304	.0295	.0294
Cu	.427	.206	.147	.108	.0916	.0820	.0751	.0654	.0585	.0521	.0476	.0418	.0357	.0330	.0316	.0309	.0303	.0305
Mo	1.03	.389	.225	.130	.0998	.0851	.0761	.0648	.0575	.0510	.0467	.0414	.0365	.0349	.0344	.0344	.0349	.0359
Sn	1.58	.563	.303	.153	.109	.0886	.0776	.0647	.0568	.0501	.0459	.0408	.0367	.0355	.0356	.0358	.0368	.0383
I	1.83	.648	.339	.165	.114	.0913	.0792	.0653	.0571	.0502	.0460	.0409	.0370	.0360	.0361	.0365	.0377	.0394
W	4.21	1.44	.708	.293	.174	.125	.101	.0763	.0640	.0544	.0492	.0437	.0405	.0402	.0409	.0418	.0438	.0465
Pt	4.75	1.64	.795	.324	.191	.135	.107	.0800	.0659	.0554	.0501	.0445	.0414	.0411	.0418	.0427	.0448	.0477
Tl	5.16	1.80	.888	.346	.204	.143	.112	.0824	.0675	.0563	.0508	.0452	.0420	.0416	.0423	.0433	.0454	.0484
Pb	5.29	1.84	.896	.356	.208	.145	.114	.0836	.0684	.0569	.0512	.0457	.0421	.0420	.0426	.0436	.0459	.0489
U	10.60	2.42	1.17	.452	.259	.176	.136	.0952	.0757	.0615	.0548	.0484	.0445	.0440	.0446	.0455	.0479	.0511
Air	.151	.134	.123	.106	.0953	.0868	.0804	.0706	.0636	.0567	.0517	.0445	.0357	.0307	.0274	.0250	.0220	.0202
NaI	1.57	.568	.305	.155	.111	.0901	.0789	.0657	.0577	.0508	.0465	.0412	.0367	.0351	.0347	.0347	.0354	.0366
H_2O	.167	.149	.136	.118	.106	.0966	.0896	.0786	.0706	.0630	.0575	.0493	.0396	.0339	.0301	.0275	.0240	.0219
Concrete	.169	.139	.124	.107	.0954	.0870	.0804	.0700	.0635	.0567	.0517	.0445	.0363	.0317	.0287	.0268	.0243	.0229
Tissue	.163	.144	.132	.115	.100	.0936	.0867	.0761	.0683	.0600	.0556	.0478	.0384	.0329	.0292	.0267	.0233	.0212

*From L. T. Templin, editor, *Reactor Physics Constants*, ANL-5800, 2nd ed., 1963; based on G. W. Grodstein National Bureau of Standards circular 583, 1957.

†Nominal densities of the elements are given in Table II.3. For air at 1 atm and 0°C, $\rho = 1.293 \times 10^{-3}$ g/cm^3; ρ (NaI) = 3.67 g/cm^3, ρ (tissue) ≃ (H_2O) = 1 g/cm^3; ρ (concrete) = 2.25–2.40 g/cm^3.

八十六學年度 工程與系統科學 系(所) ___ 組碩士班研究生入學考試

科目 核工原理 科號 ____ 共 7 頁第 7 頁 *請在試卷【答案卷】內作答

The mass absorption coefficient (μ_a/ρ) for several materials, in cm^2/g*

Material	Gamma-ray energy, MeV																	
	0.1	0.15	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.25	1.50	2	3	4	5	6	8	10
H	.0411	.0487	.0631	.0575	.0589	.0591	.0590	.0576	.0557	.0533	.0509	.0467	.0401	.0364	.0318	.0291	.0252	.0255
Be	.0183	.0217	.0237	.0256	.0263	.0264	.0263	.0256	.0248	.0237	.0227	.0210	.0183	.0164	.0151	.0141	.0127	.0118
C	.0215	.0246	.0267	.0288	.0296	.0297	.0296	.0289	.0280	.0268	.0256	.0237	.0209	.0190	.0177	.0166	.0153	.0145
N	.0224	.0249	.0267	.0288	.0296	.0297	.0298	.0289	.0280	.0268	.0256	.0236	.0211	.0193	.0180	.0171	.0158	.0151
O	.0233	.0252	.0271	.0289	.0296	.0297	.0296	.0289	.0280	.0268	.0257	.0238	.0212	.0195	.0183	.0176	.0163	.0157
Na	.0259	.0258	.0266	.0279	.0283	.0284	.0284	.0276	.0268	.0257	.0246	.0229	.0207	.0194	.0185	.0179	.0171	.0168
Mg	.0235	.0276	.0278	.0290	.0294	.0293	.0292	.0285	.0276	.0265	.0254	.0237	.0216	.0203	.0194	.0188	.0182	.0180
Al	.0373	.0283	.0275	.0283	.0287	.0286	.0286	.0278	.0270	.0259	.0248	.0232	.0212	.0200	.0192	.0188	.0183	.0182
Si	.0435	.0300	.0286	.0291	.0293	.0290	.0290	.0282	.0274	.0263	.0252	.0236	.0217	.0206	.0198	.0194	.0190	.0189
P	.0501	.0315	.0292	.0289	.0290	.0290	.0287	.0280	.0271	.0260	.0250	.0234	.0216	.0206	.0200	.0197	.0194	.0195
S	.0601	.0351	.0310	.0301	.0301	.0300	.0298	.0288	.0279	.0268	.0258	.0242	.0224	.0215	.0209	.0206	.0208	.0206
Ar	.0729	.0368	.0302	.0278	.0274	.0272	.0270	.0260	.0252	.0242	.0233	.0220	.0206	.0199	.0195	.0195	.0194	.0197
K	.0909	.0433	.0340	.0304	.0298	.0295	.0291	.0282	.0272	.0261	.0251	.0237	.0222	.0217	.0214	.0212	.0215	.0219
Ca	.111	.0489	.0367	.0318	.0309	.0304	.0300	.0290	.0279	.0268	.0258	.0244	.0230	.0225	.0222	.0223	.0225	.0231
Fe	.225	.0810	.0489	.0340	.0307	.0294	.0287	.0274	.0261	.0250	.0242	.0231	.0224	.0224	.0227	.0231	.0239	.0250
Cu	.310	.107	.0594	.0368	.0316	.0296	.0286	.0271	.0260	.0247	.0237	.0229	.0223	.0227	.0231	.0237	.0248	.0261
Mo	.922	.294	.141	.0617	.0422	.0348	.0315	.0281	.0263	.0248	.0239	.0233	.0237	.0250	.0262	.0274	.0296	.0316
Sn	1.469	.471	.222	.0873	.0534	.0403	.0346	.0294	.0268	.0248	.0239	.0233	.0243	.0259	.0276	.0291	.0316	.0339
I	1.726	.557	.260	.100	.0589	.0433	.0366	.0303	.0274	.0252	.0241	.0236	.0247	.0265	.0283	.0299	.0327	.0353
W	4.112	1.356	.631	.230	.121	.0786	.0599	.0426	.0353	.0302	.0281	.0271	.0287	.0311	.0335	.0355	.0390	.0426
Pt	4.645	1.556	.719	.262	.138	.0892	.0666	.0465	.0375	.0315	.0293	.0280	.0296	.0320	.0343	.0365	.0400	.0436
Tl	5.057	1.717	.781	.285	.152	.0972	.0718	.0491	.0393	.0326	.0301	.0288	.0304	.0326	.0349	.0354	.0406	.0446
Pb	5.193	1.753	.821	.294	.156	.0994	.0734	.0505	.0402	.0332	.0306	.0293	.0305	.0330	.0352	.0373	.0412	.0450
U	9.63	2.337	1.096	.392	.208	.132	.0968	.0628	.0482	.0383	.0346	.0324	.0332	.0352	.0374	.0394	.0443	.0474
Air	.0233	.0251	.0268	.0288	.0296	.0297	.0296	.0289	.0280	.0268	.0258	.0238	.0211	.0194	.0181	.0172	.0160	.0153
NaI	1.468	.476	.224	.0889	.0542	.0410	.0354	.0299	.0273	.0253	.0242	.0236	.0241	.0254	.0268	.0281	.0303	.0325
H_2O	.0253	.0278	.0300	.0321	.0328	.0330	.0329	.0321	.0311	.0298	.0285	.0264	.0233	.0213	.0198	.0188	.0173	.0165
Concrete	.04 6	.0300	.0289	.0294	.0297	.0296	.0295	.0287	.0276	.0272	.0256	.0239	.0216	.0203	.0194	.0183	.0180	.0177
Tissue	.0271	.0282	.0293	.0312	.0317	.0320	.0319	.0311	.0300	.0288	.0276	.0256	.0220	.0206	.0192	.0182	.0168	.0160

*From L. T. Templin, editor, *Reactor Physics Constants*, ANL-5800, 2nd ed., 1963; based on G. W. Grodstein, National Bureau of Standards circular 583, 1957.