UNIVERSITI SAINS MALAYSIA

KSCP Examination
Academic Session 2007/2008

June 2008

ZCE 331/4 – Radiation Biophysics
[Biofizik Sinaran]

Duration: 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **TEN** printed pages before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

Instruction: Answer **ANY FIVE (5)** questions only. Students are allowed to answer all questions in Bahasa Malaysia or in English.

*[**Arahan**: Jawab **MANA-MANA LIMA (5)** soalan sahaja. Pelajar dibenarkan menjawab semua soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

.../2-

1. (a) Define the term 'half life period'. What is the relation between half life and the mean life period of a sample? Name some popular types of radiation in artificial radioactivity.
[Takrifkan istilah 'half hayat period'. Apakah hubungan di antara setengah hayat dan kala min hayat? Namakan beberapa jenis sinaran yang lazim dalam keradioaktifan buatan.]

(30/100)

(b) In a radioactive process, Nitrogen – 12 is found to be decayed into Carbon – 12 with positron emission. In this process valence electron from main atom also released simultaneously. Calculate the energy released in the process and explain the important step in this decay. (Given mass of $^{12}N_7$ = 12.02278 amu, Mass of $^{12}C_6$ = 12.003803 amu)
[Dalam suatu proses radioaktif, Nitrogen – 12 didapati mereput kepada Carbon – 12 dengan pancaran positron. Dalam proses ini, elektron valens daripada atom utama juga dikeluarkan secara serentak. Hitungkan tenaga yang dikeluarkan dalam proses tersebut dan terangkan langkah penting dalam pereputan ini. (Diberi jisim $^{12}N_7$ = 12.02278 amu, Jisim of $^{12}C_6$ = 12.003803 amu)]

(20/100)

(c) A 1.8 mCi source of radon ($T_{1/2}$ = 3.83 days) is permanently implanted into a patient.
[Suatu 1.8 mCi sumber radon ($T_{1/2}$ = 3.83 hari) diimplan secara kekal ke dalam seorang pasien.]

(i) Find the decay constant.
[Cari pemalar reputan.]

(ii) Express the half life and mean life of this source in SI unit with their definition.
[Ungkapkan setengah hayat dan min hayat dalam unit SI dengan takrifannya.]

(iii) What is the relation connecting half life and mean life?
[Apakah persamaan yang menghubungkan setengah hayat dan min hayat?]

(iv) Determine the radiation emitted by radon.
[Tentukan sinaran yang dikeluarkan oleh radon.]

(50/100)

2. (a) Explain about linear attenuation coefficient of a sample and mention the various types of it.
[Terangkan mengenai pekali atenuasi linear suatu sampel dan nyatakan pelbagai jenisnya.]

(30/100)

(b) Discuss briefly the interaction of photon with matter in the Compton process.
[Bincangkan secara ringkas ineteraksi foton dengan jirim dalam proses Compton.]

(30/100)

(c) A cobalt-60 unit gives the γ ray photon exposure at a rate of 120 R/min at 1 meter when the source is 'on'. Protection regulations require that when the source is 'off' the radiation level at 1 meter distance be less than 2 mR/hr. If the emitted photons are of 0.6 MeV, determine the thickness of lead shielding required. (Given density of lead = 11.3 gm/cm^3)
[Suatu unit cobalt-60 memberikan dedahan foton sinar-γ pada kadar of 120 R/min pada jarak 1 meter bila sumber di 'on'. Peraturan perlindungan memerlukan bila sumber itu di 'off' aras sinaran pada jarak 1 meter menjadi kurang daripada 2 mR/hr. Jika foton terpancar adalah 0.6 MeV, tentukan ketebalan perisaian plumbum yang diperlukan. (Diberi ketumpatan plumbum = 11.3 gm/cm^3)]

(40/100)

3. (a) Discuss the important interactions of charged particle with matter. Compare them with the interactions of uncharged particles.
[Bincangkan interaksi penting zarah bercas dengan jirim. Bandingkan interaksi ini dengan interaksi zarah-zarah tak bercas.]

(40/100)

(b) What are the deciding parameters in the coulomb-force interactions? Define them and discuss the various cases arise in this type.
[Apakah parameter-parameter penentu dalam interaksi daya-coulomb? Takrifkannya dan bincangkan pelbagai kes yang timbul dalam jenis ini.]

(30/100)

(c) A 10 MeV positron beam is scattered by a carbon block. Use the standard values to determine the differential scattering constant and hence calculate the rate of bremsstrahlung production in this scattering interaction. (Given the slowly varying function is 12 for all the cases)
[Suatu 10 MeV alur positron diserakkan oleh suatu blok karbon. Gunakan nilai piawai untuk menentukan pemalar serakan pembezaan dan seterusnya hitungkan kadar penghasilan bremsstrahlung dalam interaksi serakan itu. (Diberi fungsi berubah secara perlahan adalah 12 untuk semua kes itu)]
(30/100)

4. (a) Describe a typical TLD reader with schematic diagram and explain the basic features.
[Perihalkan suatu pembaca TLD yang lazim digunakan dengan rajag berskema dan terangkan ciri-ciri asasnya.]
(50/100)

(b) Explain the difference between mass attenuation coefficient, mass energy transfer coefficient and mass energy absorption coefficient with suitable illustrations.
[Terangkan perbezaan di antara pekali atenuasi jisim, pekali perpindahan tenaga jisim dan pekali penyerapan tenaga jisim dengan gambaran yang sesuai.]
(50/100)

5. (a) Explain the meaning of kerma and absorbed dose
[Terangkan makna kerma dan dos terserap]
(25/100)

(b) State the assumptions used in Bragg-Gray theorem
[Nyatakn anggapan yang digunakan dalam teorem Bragg-Gray]
(25/100)

(c) Explain how the non-linear functions of radioactivity can be changed as linear relations. Use multi-cycle semi-logarithmic model sheets to display the interpretation of results. Justify your explanation using any two absorbers.
[Terangkan bagaimana fungsi tak linear keradioaktifan dapat diubah sebagai hubungan linear. Gunakan helaian model semi-logaritma multi-kitar bagi memaparkan interpretasi keputusan-keputusan. Justifikasikan penerangan anda dengan menggunakan sebarang dua penyerap.]
(30/100)

(d) The total absorption cross section in oxygen for photon of energy 1 MeV is 1.69 units and for photons of energy 2 MeV is 1.18 units whereas for a photon of energy 3 MeV it becomes 9.56 units. Justify the reasons for this contradiction.
[Jumlah keratin rentas penyerapan dalam oksigen untuk foton dengan tenaga 1 MeV adalah 1.69 unit dan untuk foton dengan tenaga 2 MeV adalah 1.18 unit. Manakala, untuk suatu foton dengan tenaga 3 MeV ianya menjadi 9.56 unit. Berikan justifikasi mengenai pertentangan ini.]

(20/100)

6. (a) What do you meant by survival curves? Explain the laboratory method of estimating the survival curve of mammalian cell. Label all the important parameters in the curve and explain their meaning.
[Apakah yang dimaksudkan dengan lengkung survival? Terangkan kaedah makmal untuk menganggarkan lengkung survival bagi sel mamalia. Labelkan semua parameter-parameter penting dalam lengkung itu dan terangkan maknanya.]

(40/100)

(b) What are the differences in the mammalian cell survival curves recorded by X-rays and α ray. Justify your observations.
[Apakah perbezaan di dalam lengkung survival sel mamalia yang dirakamkan oleh sinar-X dan sinar-α. Berikan justifikasi terhadap pemerhatian anda.]

(30/100)

(c) Write a short note on *[Tulis nota ringkas mengenai]*

(i) exposure from environment
[dedahan daripada kesekitaran]

(ii) exposure from artificial sources.
[dedahan daripada pembinaan oleh manusia.]

(30/100)

$1 \text{ kg} = 5.6095 \times 10^{29}$ MeV
1 amu = 931.50 MeV
Electron rest mass = 0.51100 MeV
Proton rest mass = 938.26 MeV
Neutron rest mass = 939.55 MeV
1 electron volt (eV) $= 1.6022 \times 10^{-19}$ J
$= 1.6022 \times 10^{-12}$ erg
1 joule (J) $= 10^7$ erg
1 coulomb (C) $= 2.9979 \times 10^9$ esu
1 gray (Gy) = 1 J/kg $= 10^2$ rad $= 10^4$ erg/g
1 sievert (Sv) = 1 J/kg

Energy–wavelength conversion:

1.23985×10^{-6} eV m
12.3985 keV Å

Exposure conversion:

1 roentgen (R) $= 2.58 \times 10^{-4}$ C/kg
1 C/kg = 3876 R

APPENDIX A.2. Conversion Factors

$1 \text{ kg} = 5.6095 \times 10^{29}$ MeV
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Energy–wavelength conversion:

1.23985×10^{-6} eV m
12.3985 keV Å

Exposure conversion:

1 roentgen (R) $= 2.58 \times 10^{-4}$ C/kg
1 C/kg = 3876 R

Carbon, Z = 6
Multiply data by 0.05014 to get cm^2/g
or by 0.005014 to get m^2/kg

Photon Energy (MeV)	Compton With and Without Coherent $\times 10^{-28}$ $m^2/atom$		Photoelectric	Nuclear and Electron Pair		Total With and Without Coherent	
	${}_e\sigma + {}_e\sigma_R$	${}_e\sigma$	${}_e\tau$	${}_e\kappa_{nuc}$	${}_e\kappa_{elec}$	${}_e\mu$	${}_e\mu - {}_e\sigma_R$
1.00 −02	6.11 +00	3.84 +00	3.93 +01	—	—	4.54 +01	4.31 +01
1.50 −02	5.06 +00	3.77 +00	1.06 +01	—	—	1.57 +01	1.44 +01
2.00 −02	4.53 +00	3.71+ 00	4.01 +00	—	—	8.54 +00	7.72 +00
3.00 −02	4.00 +00	3.58 +00	9.99 −01	—	—	5.00 +00	4.58 +00
4.00 −02	3.73 +00	3.47 +00	3.79 −01	—	—	4.10 +00	3.85 +00
5.00 −02	3.54 +00	3.37 +00	1.93 −01	—	—	3.73 +00	3.56 +00
6.00 −02	3.39 +00	3.27 +00	1.15 −01	—	—	3.51 +00	3.39 +00
8.00 −02	3.17 +00	3.10 +00	4.50 −02	—	—	3.21 +00	3.15 +00
1.00 −01	3.00 +00	2.96 +00	2.16 −02	—	—	3.02 +00	2.98 +00
1.50 −01	2.69 +00	2.66 +00	5.75 −03	—	—	2.69 +00	2.67 +00
2.00 −01	2.45 +00	2.44 +00	2.29 −03	—	—	2.45 +00	2.44 +00
3.00 −01	2.13 +00	2.12 +00	6.46 −04	—	—	2.13 +00	2.12 +00
4.00 −01	1.90 +00	1.90 +00	2.77 −04	—	—	1.91 +00	1.90 +00
5.00 −01	1.74 +00		1.49 −04	—	—	1.74 +00	
6.00 −01	1.61 +00		9.27 −05	—	—	1.61 +00	
8.00 −01	1.41 +00		4.68 −05	—	—	1.41 +00	
1.00 +00	1.27 +00		2.89 −05	—	—	1.27 +00	
1.50 +00	1.03 +00		1.35 −05	1.60 −03	—	1.03 +00	
2.00 +00	8.79 −01		8.61 −06	6.40 −03	—	8.86 −01	
3.00 +00	6.92 −01		4.82 −06	1.84 −02	2.41 −04	7.11 −01	
4.00 +00	5.77 −01		3.29 −06	2.98 −02	9.91 −04	6.08 −01	
5.00 +00	4.98 −01		2.52 −06	4.00 −02	1.95 −03	5.40 −01	
6.00 +00	4.40 −01		2.01 −06	4.90 −02	3.00 −03	4.93 −01	
8.00 +00	3.60 −01		1.44 −06	6.42 −02	5.12 −03	4.30 −01	
1.00 +01	3.07 −01		1.12 −06	7.66 −02	7.01 −03	3.90 −01	
1.50 +01	2.27 −01		—	1.00 −01	1.09 −02	3.38 −01	
2.00 +01	1.82 −01		—	1.17 −01	1.40 −02	3.14 −01	
3.00 +01	1.33 −01		—	1.41 −01	1.87 −02	2.93 −01	
4.00 +01	1.05 −01		—	1.58 −01	2.21 −02	2.86 −01	
5.00 +01	8.80 −02		—	1.71 −01	2.48 −02	2.84 −01	
6.00 +01	7.59 −02		—	1.81 −01	2.71 −02	2.84 −01	
8.00 +01	5.98 −02		—	1.96 −01	3.06 −02	2.86 −01	
1.00 +02	4.97 −02		—	2.07 −01	3.31 −02	2.90 −01	

Photon Energy (MeV)	Lead (Plumbum) ($cm^2\ g^{-1}$)			Air (Udara) ($cm^2\ g^{-1}$)		
	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ
0.5	0.1614	0.0984	0.0951	0.0868	0.0297	0.0296
0.6	0.1249	0.0737	0.0710	0.0804	0.0296	0.0293
0.8	0.0886	0.0503	0.0481	0.0706	0.0289	0.0289
1.0	0.0708	0.0396	0.0377	0.0635	0.0280	0.0278
1.5	0.0518	0.0288	0.0271	0.0517	0.0256	0.0254
2	0.0455	0.0259	0.0240	0.0444	0.0236	0.0234
3	0.0417	0.0260	0.0234	0.0358	0.0207	0.0205

...8/-

TABLE A-9

Absorption Coefficients

σ—Compton scattering; σ_k—Compton Energy Transfer; σ_{coh}—coherent scattering; τ—photoelectric; π^n—pair production by nucleus; π^e—pair production by electrons (triplet) μ/ρ—total mass; μ'/ρ—total mass excluding coherent; μ_{en}/ρ—mass energy absorption.

	Hydrogen Z = 1 5.997×10^{23} atoms/gm 5.997×10^{23} electrons/gm						Carbon Z = 6 ρ = 2.25 gm/cm³ (graphite) 0.5016×10^{23} atoms/gm 3.010×10^{23} electrons/gm					
Photon Energy (Mev)	σ	σ_k	τ	μ'/ρ	μ/ρ	μ_{en}/ρ	σ	σ_{coh}	τ	μ'/ρ	μ/ρ	μ_{en}/ρ
	$\times 10^{-24}$ cm²/atom			cm²/gm			$\times 10^{-24}$ cm²/atom			cm²/gm		
.01	.6404	.0077	.0046	.385	.385	.00986	3.84	3.04	39.3	2.16	2.32	1.97
.015	.6289	.0138	.0011	.376	.376	.0110	3.77	1.53	10.6	.721	.797	.536
.02	.6179	.0196		.369	.369	.0135	3.71	.93	4.01	.387	.434	.208
.03	.5974	.0295		.357	.357	.0185	3.58	.46	.999	.230	.253	.0594
.04	.5786	.0380		.346	.346	.0231	3.47	.24	.379	.193	.205	.0306
.05	.5614	.0451		.335	.335	.0271	3.37	.13	.193	.179	.185	.0233
.06	.5455	.0509		.326	.326	.0306	3.27	.09	.115	.170	.174	.0211
.08	.5172	.0610		.309	.309	.0362	3.10	.08	.045	.158	.162	.0205
.10	.4927	.0685		.294	.294	.0406	2.96	.06	.022	.150	.152	.0215
.15	.4436	.0812			.265	.0481	2.66	.03	.006	.134	.135	.0245
.2	.4064	.0886			.243	.0525	2.44	.02	.002	.122	.123	.0265
.3	.3534	.0958			.211	.0569	2.12	.01	.0006	.106	.107	.0287
.4	.3166	.0982			.189	.0586	1.900		.0003		.0953	.0295
.5	.2891	.0986			.173	.0593	1.735		.0001		.0870	.0297
.6	.2675	.0984			.160	.0587	1.605				.0805	.0295
.8	.2349	.0959			.140	.0574	1.410				.0707	.0288
1.0	.2112	.0929			.126	.0555	1.267				.0635	.0279
			Triplet π^e	Pair π^n					Triplet π^e	Pair π^n		
1.5	.1716	.0849		.00004	.103	.0507	1.029			.002	.0517	.0255
2	.1463	.0777		.00018	.0875	.0464	.878			.006	.0443	.0234
3	.1151	.0664	.00004	.00051	.0691	.0398	.690		.0002	.018	.0356	.0204
4	.09596	.0582	.0002	.00083	.0581	.0352	.577		.0010	.030	.0305	.0185
5	.08285	.0519	.0003	.00111	.0505	.0317	.498		.0019	.040	.0271	.0171
6	.07322	.0471	.0005	.00137	.0450	.0290	.441		.0030	.049	.0247	.0161
8	.05988	.0399	.0008	.00179	.0375	.0252	.360		.0051	.064	.0216	.0147
10	.05098	.03487	.0012	.00213	.0325	.0225	307		.0070	.078	.0196	.0138
15	.03771	.02670	.0018	.0028	.0253		.226		.011	.099	.0169	
20	.03025	.02201	.0023	.0033	.0214		.1814		.014	.116	.0156	
30	.02199	.01643	.0031	.0040	.0174		.1319		.019	.140	.0146	
40	.01746	.01327	.0037	.0045	.0153		.1048		.022	.157	.0142	
50	.01456	.01121	.0041	.0048	.0140		.0874		.025	.170	.0142	
60	.01254	.00979	.0045	.0051	.0132		.0752		.027	.180	.0142	
80	.00988	.00776	.0051	.0056	.0123		.0593		.030	.195	.0148	
100	.00820	.00651	.0056	.0059	.0118		.0492		.033	.207	.0145	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

Jadual

Oxygen, Z = 8
Multiply by 0.03764 to get cm^2/g
or by 0.003764 to get m^2/kg

Photon Energy (MeV)	Compton With and Without Coherent		Photoelectric	Nuclear and Electron Pair		Total With and Without Coherent	
	$a\sigma + a\sigma_R$	$a\sigma$	$a\tau$	$a\kappa_{nuc}$	$a\kappa_{elec}$	$a\mu$	$a\mu - a\sigma_R$
			$\times 10^{-28}\ m^2/atom$				
1.00 - 02	1.06 + 01	5.12 + 00	1.43 + 02	-	-	1.54 + 02	1.48 + 02
1.50 - 02	8.00 + 00	5.03 + 00	3.81 + 01	-	-	4.61 + 01	4.31 + 01
2.00 - 02	6.84 + 00	4.94 + 00	1.51 + 01	-	-	2.19 + 01	2.00 + 01
3.00 - 02	5.74 + 00	4.78 + 00	4.13 + 00	-	-	9.87 + 00	8.91 + 00
4.00 - 02	5.20 + 00	4.63 + 00	1.64 + 00	-	-	6.84 + 00	6.27 + 00
5.00 - 02	4.87 + 00	4.49 + 00	8.00 - 01	-	-	5.67 + 00	5.29 + 00
6.00 - 02	4.63 + 00	4.36 + 00	4.48 - 01	-	-	5.08 + 00	4.81 + 00
8.00 - 02	4.29 + 00	4.14 + 00	1.78 - 01	-	-	4.47 + 00	4.32 + 00
1.00 - 01	4.05 + 00	3.94 + 00	8.54 - 02	-	-	4.13 + 00	4.03 + 00
1.50 - 01	3.60 + 00	3.55 + 00	2.32 - 02	-	-	3.62 + 00	3.57 + 00
2.00 - 01	3.27 + 00	3.25 + 00	9.30 - 03	-	-	3.28 + 00	3.26 + 00
3.00 - 01	2.84 + 00	2.83 + 00	2.65 - 03	-	-	2.84 + 00	2.83 + 00
4.00 - 01	2.54 + 00	2.53 + 00	1.13 - 03	-	-	2.54 + 00	2.54 + 00
5.00 - 01	2.32 + 00	2.31 + 00	6.11 - 04	-	-	2.32 + 00	2.31 + 00
6.00 - 01	2.15 + 00	2.14 + 00	3.82 - 04	-	-	2.15 + 00	2.14 + 00
8.00 - 01	1.88 + 00		1.92 - 04	-	-	1.88 + 00	
1.00 + 00	1.69 + 00		1.19 - 04	-	-	1.69 + 00	
1.50 + 00	1.37 + 00		5.57 - 05	2.86 - 03	-	1.38 + 00	
2.00 + 00	1.17 + 00		3.54 - 05	1.14 - 02	-	1.18 + 00	
3.00 + 00	9.23 - 01		1.98 - 05	3.27 - 02	3.22 - 04	9.56 - 01	
4.00 + 00	7.69 - 01		1.35 - 05	5.30 - 02	1.32 - 03	8.24 - 01	
5.00 + 00	6.65 - 01		1.03 - 05	7.11 - 02	2.60 - 03	7.38 - 01	
6.00 + 00	5.87 - 01		8.22 - 06	8.70 - 02	3.99 - 03	6.78 - 01	
8.00 + 00	4.80 - 01		5.88 - 06	1.14 - 01	6.83 - 03	6.01 - 01	
1.00 + 01	4.09 - 01		4.61 - 06	1.36 - 01	9.34 - 03	5.54 - 01	
1.50 + 01	3.03 - 01		-	1.77 - 01	1.45 - 02	4.95 - 01	
2.00 + 01	2.43 - 01		-	2.08 - 01	1.87 - 02	4.69 - 01	
3.00 + 01	1.77 - 01		-	2.50 - 01	2.49 - 02	4.52 - 01	
4.00 + 01	1.41 - 01		-	2.79 - 01	2.95 - 02	4.49 - 01	
5.00 + 01	1.17 - 01		-	3.01 - 01	3.31 - 02	4.52 - 01	
6.00 + 01	1.01 - 01		-	3.19 - 01	3.61 - 02	4.56 - 01	
8.00 + 01	7.98 - 02		-	3.46 - 01	4.05 - 02	4.66 - 01	
1.00 + 02	6.62 - 02		-	3.65 - 01	4.39 - 02	4.75 - 01	

APPENDIX E. (*Continued*)

Carbon (Graphite)

ENERGY	STOPPING POWER COLLISION	STOPPING POWER RADIATIVE	STOPPING POWER TOTAL	CSDA RANGE	RADIATION YIELD	DENS.EFF. CORR. (DELTA)
MeV	MeV cm²/g	MeV cm²/g	MeV cm²/g	g/cm²		
0.0100	2.014E+01	3.150E-03	2.014E+01	2.820E-04	8.665E-05	1.920E-03
0.0125	1.694E+01	3.161E-03	1.695E+01	4.179E-04	1.036E-04	2.481E-03
0.0150	1.471E+01	3.168E-03	1.471E+01	5.767E-04	1.199E-04	3.073E-03
0.0175	1.305E+01	3.172E-03	1.305E+01	7.575E-04	1.355E-04	3.695E-03
0.0200	1.177E+01	3.176E-03	1.177E+01	9.595E-04	1.506E-04	4.347E-03
0.0250	9.913E+00	3.184E-03	9.916E+00	1.424E-03	1.796E-04	5.736E-03
0.0300	8.626E+00	3.194E-03	8.629E+00	1.966E-03	2.073E-04	7.236E-03
0.0350	7.679E+00	3.204E-03	7.682E+00	2.582E-03	2.340E-04	8.843E-03
0.0400	6.950E+00	3.215E-03	6.953E+00	3.267E-03	2.597E-04	1.055E-02
0.0450	6.372E+00	3.228E-03	6.375E+00	4.019E-03	2.847E-04	1.236E-02
0.0500	5.901E+00	3.241E-03	5.904E+00	4.835E-03	3.090E-04	1.425E-02
0.0550	5.510E+00	3.255E-03	5.513E+00	5.712E-03	3.327E-04	1.624E-02
0.0600	5.179E+00	3.270E-03	5.183E+00	6.648E-03	3.558E-04	1.832E-02
0.0700	4.652E+00	3.303E-03	4.655E+00	8.688E-03	4.008E-04	2.271E-02
0.0800	4.249E+00	3.337E-03	4.253E+00	1.094E-02	4.441E-04	2.740E-02
0.0900	3.931E+00	3.375E-03	3.935E+00	1.339E-02	4.860E-04	3.237E-02
0.1000	3.674E+00	3.414E-03	3.677E+00	1.602E-02	5.268E-04	3.760E-02
0.1250	3.204E+00	3.523E-03	3.207E+00	2.333E-02	6.243E-04	5.166E-02
0.1500	2.886E+00	3.640E-03	2.890E+00	3.156E-02	7.168E-04	6.694E-02
0.1750	2.657E+00	3.764E-03	2.661E+00	4.059E-02	8.055E-04	8.320E-02
0.2000	2.485E+00	3.896E-03	2.489E+00	5.032E-02	8.911E-04	1.003E-01
0.2500	2.245E+00	4.179E-03	2.249E+00	7.152E-02	1.055E-03	1.363E-01
0.3000	2.087E+00	4.489E-03	2.092E+00	9.462E-02	1.213E-03	1.740E-01
0.3500	1.977E+00	4.820E-03	1.981E+00	1.192E-01	1.367E-03	2.129E-01
0.4000	1.896E+00	5.173E-03	1.901E+00	1.450E-01	1.518E-03	2.524E-01
0.4500	1.835E+00	5.545E-03	1.841E+00	1.718E-01	1.668E-03	2.922E-01
0.5000	1.788E+00	5.935E-03	1.794E+00	1.993E-01	1.817E-03	3.321E-01
0.5500	1.752E+00	6.340E-03	1.758E+00	2.274E-01	1.966E-03	3.719E-01
0.6000	1.722E+00	6.759E-03	1.729E+00	2.561E-01	2.115E-03	4.114E-01
0.7000	1.679E+00	7.637E-03	1.687E+00	3.147E-01	2.416E-03	4.891E-01
0.8000	1.650E+00	8.559E-03	1.659E+00	3.745E-01	2.719E-03	5.648E-01
0.9000	1.631E+00	9.523E-03	1.640E+00	4.352E-01	3.026E-03	6.382E-01
1.0000	1.617E+00	1.053E-02	1.627E+00	4.964E-01	3.337E-03	7.091E-01
1.2500	1.599E+00	1.318E-02	1.612E+00	6.509E-01	4.133E-03	8.756E-01
1.5000	1.593E+00	1.602E-02	1.609E+00	8.062E-01	4.954E-03	1.028E+00
1.7500	1.594E+00	1.901E-02	1.613E+00	9.614E-01	5.799E-03	1.167E+00
2.0000	1.597E+00	2.213E-02	1.619E+00	1.116E+00	6.665E-03	1.295E+00
2.5000	1.608E+00	2.870E-02	1.637E+00	1.423E+00	8.450E-03	1.522E+00
3.0000	1.621E+00	3.561E-02	1.657E+00	1.727E+00	1.029E-02	1.720E+00
3.5000	1.634E+00	4.281E-02	1.677E+00	2.027E+00	1.218E-02	1.894E+00
4.0000	1.647E+00	5.026E-02	1.697E+00	2.323E+00	1.410E-02	2.051E+00
4.5000	1.658E+00	5.792E-02	1.716E+00	2.616E+00	1.606E-02	2.193E+00
5.0000	1.669E+00	6.576E-02	1.735E+00	2.906E+00	1.803E-02	2.323E+00
5.5000	1.679E+00	7.378E-02	1.753E+00	3.193E+00	2.003E-02	2.443E+00
6.0000	1.689E+00	8.193E-02	1.771E+00	3.476E+00	2.204E-02	2.555E+00
7.0000	1.706E+00	9.865E-02	1.804E+00	4.036E+00	2.610E-02	2.758E+00
8.0000	1.720E+00	1.158E-01	1.836E+00	4.585E+00	3.020E-02	2.939E+00
9.0000	1.733E+00	1.334E-01	1.867E+00	5.125E+00	3.432E-02	3.104E+00
10.0000	1.745E+00	1.513E-01	1.896E+00	5.657E+00	3.845E-02	3.256E+00
12.5000	1.769E+00	1.971E-01	1.966E+00	6.952E+00	4.877E-02	3.591E+00
15.0000	1.787E+00	2.446E-01	2.032E+00	8.202E+00	5.903E-02	3.879E+00
17.5000	1.803E+00	2.927E-01	2.095E+00	9.414E+00	6.918E-02	4.133E+00
20.0000	1.816E+00	3.417E-01	2.157E+00	1.059E+01	7.917E-02	4.361E+00
25.0000	1.836E+00	4.417E-01	2.278E+00	1.284E+01	9.861E-02	4.755E+00
30.0000	1.852E+00	5.435E-01	2.396E+00	1.498E+01	1.173E-01	5.088E+00
35.0000	1.865E+00	6.466E-01	2.512E+00	1.702E+01	1.351E-01	5.376E+00
40.0000	1.877E+00	7.508E-01	2.627E+00	1.897E+01	1.522E-01	5.628E+00
45.0000	1.886E+00	8.559E-01	2.742E+00	2.083E+01	1.685E-01	5.854E+00
50.0000	1.895E+00	9.617E-01	2.857E+00	2.262E+01	1.841E-01	6.057E+00
55.0000	1.903E+00	1.068E+00	2.971E+00	2.433E+01	1.991E-01	6.241E+00
60.0000	1.910E+00	1.175E+00	3.085E+00	2.598E+01	2.133E-01	6.411E+00
70.0000	1.922E+00	1.391E+00	3.313E+00	2.911E+01	2.401E-01	6.712E+00
80.0000	1.932E+00	1.608E+00	3.541E+00	3.203E+01	2.648E-01	6.974E+00
90.0000	1.942E+00	1.826E+00	3.768E+00	3.477E+01	2.875E-01	7.206E+00