UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 1994/95

Oktober/November 1994

ZCT 533/4 - Dosimetri dan Perlindungan Sinaran

Masa : [3 jam]

Sila pastikan bahawa kertas peperiksaan ini mengandungi LIMA muka surat yang bercetak sebelum anda memulakan peperiksaan ini. Satu set sifir (13 muka surat) diberikan.

Jawab KESEMUA LIMA soalan.
Kesemuanya wajib dijawab di dalam Bahasa Malaysia.

1. (a) Dos serapan 4 Gy pada keseluruh badan biasanya memberi maut kepada manusia. Jika tenaga setara dengan dos ini ditaburkan secara seragam di dalam seorang yang beratnya 70 kg. Tiada haba yang hilang.

Hitungkan kenaikan suhu bagi orang itu.

Anggapkan haba spesifiknya sama dengan haba spesifik air iaitu s = 4200 J kg^{-1} K^{-1}.

(10/100)

(b) Berikan komen terhadap kenyataan 4 Gy memberi maut pada manusia tetapi perubahan suhu yang berlaku hanya kecil sahaja?

(10/100)

(c) Terangkan kuantiti-kuantiti yang digunakan untuk menghuraikan medan sinaran. Suatu bim foton mempunyai taburan tenaga (MeV) seperti $\phi(E)\,dE = (10 - 2E)\,dE$. Hitungkan jumlah fluens dengan

(i) tenaga $E < 5$ MeV
(ii) tenaga $E = 5$ MeV

Hitungkan tenaga foton purata dalam julat $0 < E < 5$ MeV.

(30/100)

(d) Terangkan maksud kerma dan dedahan.
Terbitkan perhubungan antara dedahan dan kerma pelanggaran.

(25/100)

(e) Suatu sinar gama 8 MeV memasuki isipadu V dan melakukan penghasilan pasangan. Elektron dan positron yang dihasilkan mempunyai tenaga yang sama. Elektron itu menghabiskan setengah tenaga kinetiknya dalam pelanggaran sebelum ia melepas dari V. Positron itu menghabiskan tiga suku tenaga kinetiknya dalam pelanggaran sebelum ia dimusnah habiskan. Foton yang dihasilkan melepas dari V.

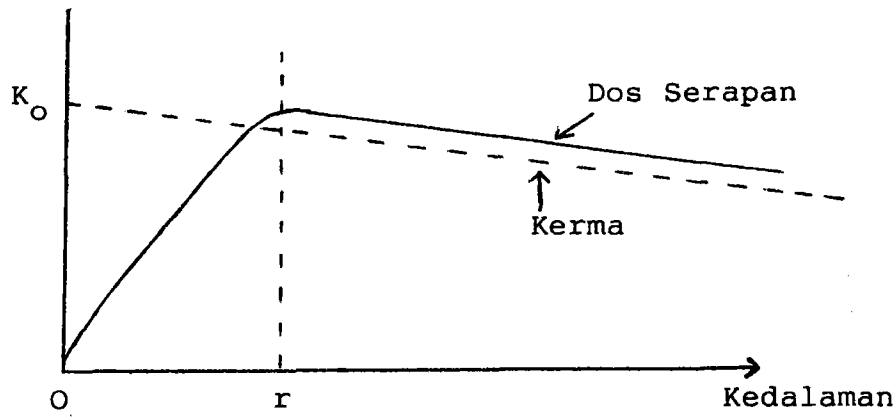
(i) Tentukan kerma dan dos serapan dalam V. $V = 1\ cm^3$ dan ketumpatannya $1\ kg\ m^{-3}$.

(ii) Tentukan tenaga foton yang dihasilkan oleh pemusnah-habisan positron.

(25/100)

2. (a) Terangkan maksud seimbangan sinaran (radiation equilibrium) dan seimbangan zarah bercas (CPE).

(15/100)



Graf di atas menunjukkan kerma dan dos serapan yang didapati apabila fantom perspex disinari dengan sinar gama yang bertenaga tinggi. Terangkan data yang diperhatikan di dalam graf.

(25/100)

(b) Nyatakan teorem kaviti Bragg-Gray. Terangkan had kegunaannya merujuk pada medan sinaran foton dan neutron.

(20/100)

(c) Suatu dosimeter udara dipagari dengan ketebalan seimbangan dinding Teflon dan polistyrene bagi tenaga 0.3 MeV dan 1.0 MeV.

(i) Hitungkan nisbah purata dos udara di dalam dosimeter dengan dos udara dalam keadaan CPE bagi setiap tenaga. Anggapkan d = 1 dan O dalam teori Burlin.
Dosimeter yang manakah yang lebih berdekatan dengan udara di dalam dosimeter.

(ii) Sekarang dosimeter udara dengan dinding Teflon diletak di dalam fantom poliethilene. Dos puratanya di dalam udara bagi dosimeter ialah 0.2 Gy bagi 1 MeV sinar gama.
Hitungkan dos serapan dalam fantom pada kedudukan yang sama bagi d = 1 dan d = 0.

(40/100)

3. (a) Anda perlu melakukan kalibrasi dalam udara bagi suatu mesin sinar-X 200 kV. Nyatakan semua langkah dan data sesuai yang perlu dibacakan dan direkodkan dalam mengkalibrasi bim dalam ungkapan dedahan.

(25/100)

(b) Selepas mengkalibrasikan bim sinar-X, anda perlu hubungkan dedahan pada dos serapan dalam air. Di dalam terbitan perhubungan ini, nyatakan semua anggapan yang digunakan.

(25/100)

(c) Suatu chamber pengionan jenis Farmer digunakan dalam penentuan dos serapan dalam fantom air yang disinari dengan sinar gama Co-60. Suatu "tubing" getah yang mengelingi chamber itu melindunginya dari air. Chamber diletak dengan pusatnya pada titik P. Selepas suatu penyinaran, elektrometer memberi bacaan skala 74.0. Tekanan atmosferanya 740 torr dan suhu chambernya 25°C. Faktor kalibrasi dedahannya 1.06 Rontgen per bacaan skala bagi Co-60 penyinaran.

(i) Tentukan dos serapannya dalam fantom. Jejari luar bagi chamber dengan cap ialah 0.8 cm.

(ii) Tentukan faktor kalibrasi dos serapan.

(50/100)

4. (a) Suatu bim sempit sinar gama melalui 2 cm plumbum. Bim datang mengandungi 30% 0.4 MeV foton dan 70% 1.5 MeV foton.

(i) Hitungkan nisbah fluens tuju yang melalui plumbum.

(ii) Hitungkan nisbah tenaga fluens tuju yang melalui plumbum.

(25/100)

(b) Terangkan maksud faktor buildup. Sekarang suatu bim lebar digunakan dalam 4(a). Terangkan bagaimana anda anggarkan faktor buildupnya.

(15/100)

(c) Huraikan jenis tindakbalas neutron terma yang berlaku dalam tisu. Apakah sumbangan relatifnya dalam sebutan saiz tisu.

(15/100)

(d) Huraikan langkah-langkah bagi kalibrasi suatu chamber ion yang setara tisu bagi dosimetri n + γ. Terbitkan persamaan yang sesuai dan tunjukkan bahawa

$$\left(\frac{B}{A}\right)_{TE} = \left(F_n\right)^{TE}_{tisu} \frac{\left(\bar{W}_\gamma/e\right)_g}{\left(\bar{W}_n/e\right)_g}$$

(45/100)

5. (a) Terangkan maksud tenaga spesifik Z dan dos serapan D dan kepentingannya.

(15/100)

(b) Suatu nukleus sel sfera bergarispusat 2 μm dan ianya setara air. Anggapkan zarah pengionan terus melalui (lintasan lurus) nukleus. Hitungkan bilangan pengionan purata yang dihasilkan dalam

(i) nukleus sel oleh 10 MeV elektron melalui garispusat.

(ii) nukleus sel oleh 10 MeV zarah alfa melalui garispusat.

Terangkan kesimpulan yang anda dapat mengenai kerosakan yang dihasil oleh dua jenis sinaran itu.

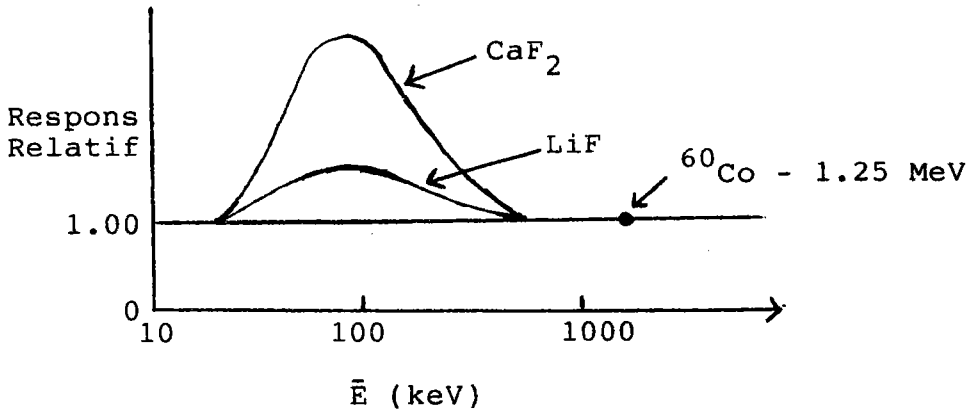
$$\left.\begin{aligned} (\bar{W}/e)_e &= 29.6 \text{ J/C} \\ (\bar{W}/e)_\alpha &= 37.6 \text{ J/C} \\ (d\bar{T}/dx)_\alpha &= 5.022 \times 10^4 \text{ MeV m}^{-1} \end{aligned}\right\} \text{ dalam air}$$

(30/100)

(c) Bincangkan model-model yang digunakan untuk mendapati anggaran risiko bagi kanser dalam kawasan dos rendah. Katakan kepentingannya dalam perlindungan sinaran .

(30/100)

(d) Bacaan relatif per unit dedahan bagi TLD, LiF dan CaF_2 merujuk pada tenaga $\bar{E}$ adalah seperti di bawah.



Bincangkan dengan menggunakan data dari jadual yang diberikan, respons relatif bagi LiF dan CaF_2 dari 20 keV ke 1000 keV.

(25/100)

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APPENDIX A.2. Conversion Factors

1 kg = 5.6095×10^{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) = 1.6022×10^{-19} J
= 1.6022×10^{-12} erg
1 joule (J) = 10^7 erg
1 coulomb (C) = 2.9979×10^9 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) = 2.58×10^{-4} C/kg
1 C/kg = 3876 R

APPENDIX B.1. Data Table of the Elements

Element	Symbol	At. No. Z	At. Wt. A	Z/A	$10^{-23}\ N_A Z/A$[a]	Density[b] (g/cm^3)	K-edge (keV)	$L1$-edge (keV)	I[c] (eV)
Hydrogen	H	1	1.008	.9922	5.975	8.374×10^{-5}	0.014	—	19.2
Helium	He	2	4.003	.4997	3.009	1.663×10^{-4}	0.025	—	41.8
Lithium	Li	3	6.941	.4322	2.603	0.533	0.055	—	40.0
Beryllium	Be	4	9.012	.4438	2.673	1.848	0.111	—	63.7
Boron	B	5	10.81	.4625	2.785	2.34–2.37	0.188	—	—
Carbon (graphite)	C	6	12.01	.4995	3.008	1.9–2.3	0.284	—	78.0
Nitrogen	N	7	14.01	.4998	3.010	1.165×10^{-3}	0.402	—	82.0
Oxygen	O	8	16.00	.5000	3.011	1.331×10^{-3}	0.532	0.024	95.0
Fluorine	F	9	19.00	.4737	2.853	1.580×10^{-3}	0.685	0.031	—
Neon	Ne	10	20.18	.4956	2.984	8.385×10^{-4}	0.867	0.045	137
Sodium	Na	11	22.99	.4785	2.881	0.969	1.07	0.063	149
Magnesium	Mg	12	24.30	.4937	2.973	1.735	1.30	0.089	156
Aluminum	Al	13	26.98	.4818	2.901	2.69	1.56	0.118	166
Silicon	Si	14	28.09	.4985	3.002	2.32	1.84	0.149	173
Phosphorus	P	15	30.97	.4843	2.916	1.82–2.69	2.15	0.189	—
Sulfur	S	16	32.06	.4991	3.005	1.954, 2.07	2.47	0.229	—
Chlorine	Cl	17	35.45	.4795	2.888	2.995×10^{-3}	2.82	0.270	—
Argon	Ar	18	39.95	.4506	2.713	1.662×10^{-3}	3.20	0.320	188
Potassium	K	19	39.10	.4860	2.926	0.860	3.61	0.377	190
Calcium	Ca	20	40.08	.4990	3.005	1.55	4.04	0.438	191
Scandium	Sc	21	44.96	.4671	2.813	2.980	4.49	0.500	—
Titanium	Ti	22	47.90	.4593	2.766	4.54	4.97	0.564	233
Vanadium	V	23	50.94	.4515	2.719	6.10	5.47	0.628	245
Chromium	Cr	24	52.00	.4616	2.780	7.18	5.99	0.695	—
Manganese	Mn	25	54.94	.4551	2.740	7.21–7.44	6.54	0.769	272
Iron	Fe	26	55.85	.4656	2.804	7.86	7.11	0.846	286
Cobalt	Co	27	58.93	.4581	2.759	8.9	7.71	0.926	297
Nickel	Ni	28	58.71	.4769	2.872	8.88	8.33	1.01	311

APPENDIX B.1. (*Continued*)

Element	Symbol	At. No. Z	At. Wt. A	Z/A	$10^{-23}\ N_A Z/A$[a]	Density[b] (g/cm^3)	K-edge (keV)	$L1$-edge (keV)	I[c] (eV)
Lanthanum	La	57	138.9	.4104	2.471	6.13	38.9	6.27	—
Cerium	Ce	58	140.1	.4139	2.494	6.64	40.4	6.55	—
Praeseodymium	Pr	59	140.9	.4187	2.522	6.64, 6.77	42.0	6.83	—
Neodymium	Nd	60	144.2	.4160	2.505	6.80, 7.01	43.6	7.13	—
Promethium	Pm	61	(145)	.421	2.53	7.20	45.2	7.43	—
Samarium	Sm	62	150.4	.4122	2.482	7.40, 7.52	46.8	7.74	—
Europium	Eu	63	152.0	.4146	2.497	5.23	48.5	8.05	—
Gadolinium	Gd	64	157.2	.4070	2.451	7.88	50.2	8.38	591
Terbium	Tb	65	158.9	.4090	2.463	8.23	52.0	8.71	—
Dysprosium	Dy	66	162.5	.4062	2.446	8.52	53.8	9.05	—
Holmium	Ho	67	164.9	.4062	2.446	8.77	55.6	9.39	—
Erbium	Er	68	167.3	.4066	2.448	9.04	57.5	9.75	—
Thulium	Tm	69	168.9	.4084	2.460	9.29	59.4	10.1	—
Ytterbium	Yb	70	173.0	.4045	2.436	6.54, 6.96	61.3	10.5	—
Lutetium	Lu	71	175.0	.4058	2.444	9.81	63.3	10.9	—
Hafnium	Hf	72	178.5	.4034	2.429	13.29	65.4	11.3	—
Tantalum	Ta	73	180.9	.4034	2.429	16.65	67.4	11.7	718
Tungsten	W	74	183.8	.4025	2.424	19.3	69.5	12.1	727
Rhenium	Re	75	186.2	.4028	2.426	20.98	71.7	12.5	—
Osmium	Os	76	190.2	.3996	2.406	22.57	73.9	13.0	—
Iridium	Ir	77	192.2	.4006	2.412	22.39	76.1	13.4	—
Platinum	Pt	78	195.1	.3998	2.408	21.41	78.4	13.9	790
Gold	Au	79	197.0	.4011	2.415	19.29	80.7	14.4	790
Mercury	Hg	80	200.6	.3988	2.402	13.52	83.1	14.8	800
Thallium	Tl	81	204.4	.3963	2.387	11.83	85.5	15.3	—
Lead	Pb	82	207.2	.3958	2.383	11.33	88.0	15.9	823
Bismuth	Bi	83	209.0	.3972	2.392	9.73	90.5	16.4	—
Polonium	Po	84	(210)	.400	2.41	9.32	93.1	16.9	—

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Appendix B.2. Data Table for Compounds and Mixtures[a]

Material	Density (g/cm^3)[c]	Electron density (10^{23} e/g)	I (eV)[d]
A-150 plastic[b]	1.127	3.306	65.1
Adipose tissue (Fat, ICRP)[b]	0.92	3.363	63.2
Air[b]	1.205×10^{-3}	3.006	85.7
Bone, cortical (ICRP)[b]	1.85	3.139	106.4
Calcium fluoride, CaF_2	3.18	2.931	166
Carbon dioxide, CO_2	1.842×10^{-3}	3.010	85.0
Cesium iodide, CsI	4.51	2.503	553
Lithium fluoride, LiF	2.64	2.786	94.0
Lucite, $(C_5H_8O_2)_n$	1.19	3.248	74.0
Muscle, skeletal (ICRP)[b]	1.04	3.308	75.3
Mylar, $(C_{10}H_8O_4)_n$	1.40	3.134	78.7
Nylon, type 6 $(C_6H_{11}NO)_n$	1.14	3.299	63.9
Polycarbonate $(C_{16}H_{14}O_3)_n$	1.20	3.173	73.1
Polyethylene $(C_2H_4)_n$	0.94	3.435	57.4
Polyimide $(C_{22}H_{10}N_2O_5)$	1.42	3.087	79.6
Polypropylene $(C_3H_5)_n$	0.90	3.372	59.2
Polystyrene $(C_8H_8)_n$	1.06	3.238	68.7
Polyvinyl Chloride $(C_2H_3Cl)_n$	1.30	3.083	108.2
Pyrex (borosilicate glass)[b]	2.23	2.993	134
Silicon dioxide, SiO_2	2.32	3.007	139.2
Silver bromide, AgBr	6.47	2.629	487
Sodium iodide, NaI	3.67	2.571	452
Teflon, $(C_2F_4)_n$	2.20	2.890	99.1
TE gas (methane-based)[b]	1.064×10^{-3}	3.312	61.2
TE gas (propane-based)[b]	1.826×10^{-3}	3.314	59.5
TE liquid (no sucrose)[b]	1.070	3.313	74.2
Water, H_2O	0.9982	3.343	75.0

[a]Data from Berger and Seltzer (1983)
[b]See compositions in Appendix B.3
[c]Assuming $T = 20°C.$, $P = 1$ atm., and Charles' Law for gases applies.
[d]I is the mean excitation potential for stopping power, see Chapter 8.

APPENDIX D.3. *(Continued)*

Photon Energy (MeV)	Tin			Photon Energy (MeV)	Lead		
	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ		μ/ρ	μ_{tr}/ρ	μ_{en}/ρ
0.0010	11130	11110	11110	M_1 edge	—		
0.0015	3960	3950	3950	0.003854	1493	1454	1453
0.0020	1963	1954	1954				
0.0030	713	705	705	0.004	1333	1298	1297
				0.005	767	747	747
0.0039288	367	360	360	0.006	493	479	479
L_3 edge				0.008	238	230	230
0.0039288	1118	1067	1067				
				0.010	136.6	131.0	130.7
0.0040	1067	1019	1019				
				0.0130406	70.1	66.2	66.0
0.0041573	973	930	930	L_3 edge			
L_2 edge				0.0130406	165.7	128.8	128.8
0.0041573	1244	1187	1187				
				0.015	114.7	91.7	91.7
0.0044648	1016	971	971				
L_1 edge				0.0152053	112.0	89.6	89.6
0.0044648	1264	1207	1207	L_2 edge			
				0.0152053	145.4	113.0	113.0
0.005	919	880	880				
0.006	561	540	539	0.015855	129.3	101.7	101.6
0.008	259	250	249	L_1 edge			
				0.015855	159.2	123.0	123.0
0.010	141.6	136.5	136.4				
0.015	45.8	43.7	43.6	0.02	85.5	69.2	69.1
0.020	21.2	19.83	19.81	0.03	29.1	24.6	24.6

0.0291947	7.61	6.83	6.82	0.04	13.80	11.83	11.78
K edge				0.05	7.71	6.57	6.54
0.0291947	45.4	16.70	16.69	0.06	4.87	4.11	4.08
				0.08	2.37	1.924	1.908
0.030	42.1	16.18	16.17	0.088005	1.865	1.494	1.481
0.04	18.77	9.97	9.96	K edge			
0.05	10.20	6.25	6.24	0.088005	7.30	2.47	2.47
0.06	6.34	4.20	4.19				
0.08	3.07	2.19	2.18	0.10	5.78	2.28	2.28
				0.15	2.07	1.164	1.154
0.10	1.720	1.257	1.250	0.2	1.014	0.637	0.629
0.15	0.634	0.446	0.442	0.3	0.406	0.265	0.259
0.20	0.333	0.211	0.209				
0.30	0.1649	0.0853	0.0843	0.4	0.233	0.1474	0.1432
				0.5	0.1614	0.0984	0.0951
0.4	0.1163	0.0536	0.0530	0.6	0.1249	0.0737	0.0710
0.5	0.0948	0.0423	0.0416	0.8	0.0886	0.0503	0.0481
0.6	0.0811	0.0358	0.0353				
0.8	0.0667	0.0301	0.0294	1.0	0.0708	0.0396	0.0377
				1.5	0.0518	0.0288	0.0271
1.0	0.0578	0.0270	0.0264	2	0.0455	0.0259	0.0240
1.5	0.0462	0.0233	0.0226	3	0.0417	0.0260	0.0234
2.0	0.0410	0.0220	0.0210				
3.0	0.0366	0.0219	0.0205	4	0.0415	0.0281	0.0245
				5	0.0424	0.0306	0.0259
4	0.0355	0.0232	0.0212	6	0.0436	0.0331	0.0272
5	0.0353	0.0247	0.0221	8	0.0467	0.0378	0.0294
6	0.0357	0.0262	0.0230				
8	0.0370	0.0292	0.0245	10	0.0496	0.0419	0.0310
10	0.0387	0.0319	0.0258				

APPENDIX D.3. (*Continued*)

Photon Energy (MeV)	Air			Water			ICRU Compact Bone			ICRU Striated Muscle		
	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ
0.01	5.04	4.61	4.61	5.21	4.79	4.79	20.3	19.2	19.2	5.30	4.87	4.87
0.015	1.56	1.27	1.27	1.60	1.28	1.28	6.32	5.84	5.84	1.64	1.32	1.32
0.02	0.758	0.511	0.511	0.778	0.512	0.512	2.79	2.46	2.46	0.796	0.533	0.533
0.03	0.350	0.148	0.148	0.371	0.149	0.149	0.962	0.720	0.720	0.375	0.154	0.154
0.04	0.248	0.0668	0.0668	0.267	0.0677	0.0677	0.511	0.304	0.304	0.267	0.0701	0.0701
0.05	0.206	0.0406	0.0406	0.225	0.0418	0.0418	0.346	0.161	0.161	0.224	0.0431	0.0431
0.06	0.187	0.0305	0.0305	0.205	0.0320	0.0320	0.273	0.0998	0.0998	0.204	0.0328	0.0328
0.08	0.167	0.0243	0.0243	0.185	0.0262	0.0262	0.209	0.0537	0.0537	0.183	0.0264	0.0264
0.10	0.155	0.0234	0.0234	0.171	0.0256	0.0256	0.181	0.0387	0.0387	0.170	0.0256	0.0256
0.15	0.136	0.0250	0.0250	0.151	0.0277	0.0277	0.150	0.0305	0.0305	0.150	0.0275	0.0275
0.2	0.124	0.0268	0.0268	0.137	0.0297	0.0297	0.133	0.0301	0.0301	0.136	0.0294	0.0294
0.3	0.107	0.0287	0.0287	0.119	0.0319	0.0319	0.114	0.0310	0.0310	0.118	0.0317	0.0317
0.4	0.0954	0.0295	0.0295	0.106	0.0328	0.0328	0.102	0.0315	0.0315	0.105	0.0325	0.0325
0.5	0.0868	0.0297	0.0296	0.0966	0.0330	0.0330	0.0926	0.0317	0.0317	0.0958	0.0328	0.0328
0.6	0.0804	0.0296	0.0295	0.0894	0.0329	0.0329	0.0856	0.0315	0.0314	0.0886	0.0326	0.0325
0.8	0.0706	0.0289	0.0289	0.0785	0.0321	0.0321	0.0751	0.0307	0.0306	0.0778	0.0318	0.0318
1.0	0.0635	0.0280	0.0278	0.0706	0.0311	0.0309	0.0675	0.0297	0.0295	0.0699	0.0308	0.0306
1.5	0.0517	0.0256	0.0254	0.0575	0.0284	0.0282	0.0549	0.0272	0.0270	0.0570	0.0282	0.0280
2	0.0444	0.0236	0.0234	0.0493	0.0262	0.0260	0.0472	0.0251	0.0249	0.0489	0.0259	0.0257
3	0.0358	0.0207	0.0205	0.0396	0.0229	0.0227	0.0382	0.0221	0.0219	0.0392	0.0227	0.0225
4	0.0308	0.0189	0.0186	0.0340	0.0209	0.0206	0.0331	0.0204	0.0200	0.0337	0.0207	0.0204
5	0.0276	0.0178	0.0174	0.0303	0.0195	0.0191	0.0297	0.0192	0.0187	0.0300	0.0193	0.0189
6	0.0252	0.0168	0.0164	0.0277	0.0185	0.0180	0.0274	0.0184	0.0178	0.0274	0.0183	0.0178
8	0.0223	0.0157	0.0152	0.0243	0.0170	0.0166	0.0244	0.0173	0.0167	0.0240	0.0169	0.0164
10	0.0205	0.0151	0.0145	0.0222	0.0162	0.0157	0.0226	0.0168	0.0159	0.0219	0.0160	0.0155

APPENDIX D.3. *(Continued)*

Photon Energy (MeV)	Polystyrene			Methyl Methacrylate, Lucite, Plexiglas, Perspex			Polyethylene			Pyrex glass		
	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ	μ/ρ	μ_{tr}/ρ	μ_{en}/ρ
0.01	2.17	1.82	1.82	3.31	2.91	2.91	2.04	1.69	1.69	17.1	16.5	16.5
0.015	0.764	0.495	0.495	1.07	0.783	0.783	0.737	0.461	0.461	5.11	4.75	4.75
0.02	0.429	0.193	0.193	0.555	0.310	0.310	0.425	0.180	0.180	2.24	1.94	1.94
0.03	0.261	0.0562	0.0562	0.300	0.0899	0.0899	0.268	0.0535	0.0535	0.785	0.554	0.554
0.04	0.216	0.0300	0.0300	0.233	0.0437	0.0437	0.225	0.0295	0.0295	0.430	0.232	0.232
0.05	0.197	0.0236	0.0236	0.205	0.0301	0.0301	0.207	0.0238	0.0238	0.299	0.122	0.122
0.06	0.186	0.0218	0.0218	0.191	0.0254	0.0254	0.196	0.0225	0.0225	0.241	0.0768	0.0768
0.08	0.173	0.0217	0.0217	0.176	0.0232	0.0232	0.183	0.0228	0.0228	0.190	0.0428	0.0428
0.10	0.164	0.0231	0.0231	0.165	0.0238	0.0238	0.173	0.0243	0.0243	0.166	0.0325	0.0325
0.15	0.145	0.0263	0.0263	0.146	0.0266	0.0266	0.154	0.0279	0.0279	0.139	0.0274	0.0274
0.2	0.132	0.0286	0.0286	0.133	0.0287	0.0287	0.140	0.0303	0.0303	0.125	0.0276	0.0276
0.3	0.115	0.0309	0.0309	0.115	0.0310	0.0310	0.122	0.0328	0.0328	0.107	0.0289	0.0289
0.4	0.103	0.0318	0.0318	0.103	0.0318	0.0318	0.109	0.0337	0.0337	0.0953	0.0295	0.0295
0.5	0.0937	0.0321	0.0321	0.0939	0.0322	0.0322	0.0994	0.0340	0.0340	0.0868	0.0297	0.0297
0.6	0.0867	0.0319	0.0318	0.0869	0.0319	0.0319	0.0919	0.0338	0.0337	0.0801	0.0295	0.0294
0.8	0.0761	0.0311	0.0310	0.0763	0.0312	0.0311	0.0807	0.0330	0.0329	0.0704	0.0288	0.0287
1.0	0.0683	0.0300	0.0300	0.0686	0.0302	0.0301	0.0725	0.0319	0.0319	0.0633	0.0279	0.0277
1.5	0.0557	0.0275	0.0275	0.0559	0.0276	0.0275	0.0591	0.0292	0.0291	0.0515	0.0254	0.0252
2	0.0476	0.0253	0.0252	0.0478	0.0254	0.0253	0.0505	0.0268	0.0267	0.0444	0.0235	0.0233
3	0.0381	0.0221	0.0219	0.0383	0.0222	0.0220	0.0403	0.0234	0.0232	0.0360	0.0209	0.0207
4	0.0326	0.0200	0.0198	0.0329	0.0202	0.0199	0.0345	0.0211	0.0209	0.0314	0.0194	0.0190
5	0.0289	0.0185	0.0182	0.0292	0.0187	0.0184	0.0305	0.0195	0.0192	0.0284	0.0184	0.0179
6	0.0263	0.0174	0.0171	0.0266	0.0177	0.0173	0.0276	0.0182	0.0180	0.0263	0.0178	0.0171
8	0.0227	0.0159	0.0155	0.0231	0.0162	0.0158	0.0238	0.0166	0.0162	0.0237	0.0170	0.0163
10	0.0206	0.0150	0.0145	0.0210	0.0153	0.0148	0.0215	0.0155	0.0151	0.0221	0.0166	0.0157

APPENDIX D.4. Mass Energy-Absorption Coefficients μ_{en}/ρ (cm^2/g) for Various Media[a]

γ-Ray Energy (MeV)	Li	F	LiF	Teflon $(CF_2)_n$	CaF_2	CaF_2:Mn[b]
0.01	0.150	7.61	5.61	6.26	50.7	51.7
0.015	0.0426	2.05	1.51	1.69	15.7	16.1
0.02	0.0205	0.821	0.607	0.674	6.66	6.86
0.03	0.0118	0.233	0.174	0.191	1.96	2.03
0.04	0.0115	0.100	0.0763	0.0833	0.818	0.850
0.05	0.0125	0.0566	0.0448	0.0486	0.419	0.436
0.06	0.0137	0.0391	0.0323	0.0348	0.247	0.256
0.08	0.0159	0.0270	0.0240	0.0254	0.114	0.118
0.10	0.0178	0.0241	0.0224	0.0235	0.0677	0.0697
0.15	0.0210	0.0243	0.0234	0.0243	0.0373	0.0379
0.2	0.0229	0.0256	0.0249	0.0258	0.0315	0.0317
0.3	0.0248	0.0273	0.0266	0.0276	0.0296	0.0296
0.4	0.0255	0.0281	0.0274	0.0284	0.0295	0.0295
0.5	0.0258	0.0282	0.0276	0.0286	0.0293	0.0293
0.6	0.0256	0.0281	0.0274	0.0284	0.0290	0.0290
0.8	0.0250	0.0273	0.0267	0.0277	0.0281	0.0281
1.0	0.0242	0.0264	0.0258	0.0268	0.0271	0.0270
1.5	0.0221	0.0241	0.0236	0.0244	0.0248	0.0247
2.0	0.0203	0.0222	0.0217	0.0225	0.0229	0.0229
3.0	0.0175	0.0196	0.0190	0.0198	0.0205	0.0205
4.0	0.0156	0.0179	0.0173	0.0180	0.0192	0.0192
5.0	0.0142	0.0168	0.0161	0.0169	0.0184	0.0184
6.0	0.0131	0.0160	0.0152	0.0160	0.0179	0.0179
8.0	0.0117	0.0150	0.0141	0.0149	0.0175	0.0175
10.0	0.0107	0.0144	0.0134	0.0143	0.0173	0.0173

[a]Data for Li, F, LiF, and Teflon are taken from Sinclair (1969); those for CaF_2 and CaF_2:Mn are from Attix (1970). Both references were derived from the data of J. H. Hubbell, as published in the review by Evans (1968).
[b]CaF_2:Mn (TLD phosphor) is 49.5% Ca, 48.4% F, and 2.1% Mn by weight.

Air (Dry)

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	1.975E+01	3.897E-03	1.976E+01	2.883E-04	1.082E-04	0.0
0.0125	1.663E+01	3.921E-03	1.663E+01	4.269E-04	1.299E-04	0.0
0.0150	1.445E+01	3.937E-03	1.445E+01	5.886E-04	1.506E-04	0.0
0.0175	1.283E+01	3.946E-03	1.283E+01	7.726E-04	1.706E-04	0.0
0.0200	1.157E+01	3.954E-03	1.158E+01	9.781E-04	1.898E-04	0.0
0.0250	9.753E+00	3.966E-03	9.757E+00	1.451E-03	2.267E-04	0.0
0.0300	8.492E+00	3.976E-03	8.496E+00	2.001E-03	2.618E-04	0.0
0.0350	7.563E+00	3.986E-03	7.567E+00	2.626E-03	2.955E-04	0.0
0.0400	6.848E+00	3.998E-03	6.852E+00	3.322E-03	3.280E-04	0.0
0.0450	6.281E+00	4.011E-03	6.285E+00	4.085E-03	3.594E-04	0.0
0.0500	5.819E+00	4.025E-03	5.823E+00	4.912E-03	3.900E-04	0.0
0.0550	5.435E+00	4.040E-03	5.439E+00	5.801E-03	4.197E-04	0.0
0.0600	5.111E+00	4.057E-03	5.115E+00	6.750E-03	4.488E-04	0.0
0.0700	4.593E+00	4.093E-03	4.597E+00	8.817E-03	5.049E-04	0.0
0.0800	4.198E+00	4.133E-03	4.202E+00	1.110E-02	5.590E-04	0.0
0.0900	3.886E+00	4.175E-03	3.890E+00	1.357E-02	6.112E-04	0.0
0.1000	3.633E+00	4.222E-03	3.637E+00	1.623E-02	6.618E-04	0.0
0.1250	3.172E+00	4.348E-03	3.177E+00	2.362E-02	7.826E-04	0.0
0.1500	2.861E+00	4.485E-03	2.865E+00	3.193E-02	8.968E-04	0.0
0.1750	2.637E+00	4.633E-03	2.642E+00	4.103E-02	1.006E-03	0.0
0.2000	2.470E+00	4.789E-03	2.474E+00	5.082E-02	1.111E-03	0.0
0.2500	2.236E+00	5.126E-03	2.242E+00	7.212E-02	1.311E-03	0.0
0.3000	2.084E+00	5.495E-03	2.089E+00	9.527E-02	1.502E-03	0.0
0.3500	1.978E+00	5.890E-03	1.984E+00	1.199E-01	1.688E-03	0.0
0.4000	1.902E+00	6.311E-03	1.908E+00	1.456E-01	1.869E-03	0.0
0.4500	1.845E+00	6.757E-03	1.852E+00	1.722E-01	2.048E-03	0.0
0.5000	1.802E+00	7.223E-03	1.809E+00	1.995E-01	2.225E-03	0.0
0.5500	1.769E+00	7.708E-03	1.776E+00	2.274E-01	2.401E-03	0.0
0.6000	1.743E+00	8.210E-03	1.751E+00	2.558E-01	2.577E-03	0.0
0.7000	1.706E+00	9.258E-03	1.715E+00	3.135E-01	2.929E-03	0.0
0.8000	1.683E+00	1.036E-02	1.694E+00	3.722E-01	3.283E-03	0.0
0.9000	1.669E+00	1.151E-02	1.681E+00	4.315E-01	3.638E-03	0.0
1.0000	1.661E+00	1.271E-02	1.674E+00	4.912E-01	3.997E-03	0.0
1.2500	1.655E+00	1.588E-02	1.671E+00	6.408E-01	4.906E-03	0.0
1.5000	1.661E+00	1.927E-02	1.680E+00	7.900E-01	5.836E-03	0.0
1.7500	1.672E+00	2.284E-02	1.694E+00	9.382E-01	6.784E-03	0.0
2.0000	1.684E+00	2.656E-02	1.711E+00	1.085E+00	7.748E-03	0.0
2.5000	1.712E+00	3.437E-02	1.747E+00	1.374E+00	9.716E-03	0.0
3.0000	1.740E+00	4.260E-02	1.783E+00	1.658E+00	1.173E-02	0.0
3.5000	1.766E+00	5.115E-02	1.817E+00	1.935E+00	1.377E-02	0.0
4.0000	1.790E+00	5.999E-02	1.850E+00	2.208E+00	1.583E-02	0.0
4.5000	1.812E+00	6.908E-02	1.882E+00	2.476E+00	1.792E-02	0.0
5.0000	1.833E+00	7.838E-02	1.911E+00	2.740E+00	2.001E-02	0.0
5.5000	1.852E+00	8.787E-02	1.940E+00	2.999E+00	2.211E-02	0.0
6.0000	1.870E+00	9.754E-02	1.968E+00	3.255E+00	2.422E-02	0.0
7.0000	1.902E+00	1.173E-01	2.020E+00	3.757E+00	2.845E-02	0.0
8.0000	1.931E+00	1.376E-01	2.068E+00	4.246E+00	3.269E-02	0.0
9.0000	1.956E+00	1.584E-01	2.115E+00	4.724E+00	3.692E-02	0.0
10.0000	1.979E+00	1.795E-01	2.159E+00	5.192E+00	4.113E-02	0.0
12.5000	2.029E+00	2.337E-01	2.262E+00	6.323E+00	5.156E-02	0.0
15.0000	2.069E+00	2.895E-01	2.359E+00	7.405E+00	6.181E-02	0.0
17.5000	2.104E+00	3.464E-01	2.451E+00	8.444E+00	7.185E-02	0.0
20.0000	2.134E+00	4.042E-01	2.539E+00	9.446E+00	8.167E-02	0.0
25.0000	2.185E+00	5.219E-01	2.707E+00	1.135E+01	1.006E-01	0.0
30.0000	2.226E+00	6.417E-01	2.868E+00	1.315E+01	1.186E-01	7.636E-03
35.0000	2.257E+00	7.630E-01	3.020E+00	1.485E+01	1.357E-01	5.984E-02
40.0000	2.282E+00	8.855E-01	3.167E+00	1.646E+01	1.520E-01	1.378E-01
45.0000	2.302E+00	1.009E+00	3.311E+00	1.801E+01	1.676E-01	2.266E-01
50.0000	2.319E+00	1.133E+00	3.452E+00	1.948E+01	1.825E-01	3.192E-01
55.0000	2.334E+00	1.258E+00	3.592E+00	2.090E+01	1.968E-01	4.120E-01
60.0000	2.347E+00	1.384E+00	3.731E+00	2.227E+01	2.104E-01	5.029E-01
70.0000	2.369E+00	1.637E+00	4.006E+00	2.486E+01	2.361E-01	6.762E-01
80.0000	2.387E+00	1.892E+00	4.279E+00	2.727E+01	2.598E-01	8.365E-01
90.0000	2.403E+00	2.148E+00	4.551E+00	2.954E+01	2.818E-01	9.842E-01

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APPENDIX E. *(Continued)*

Water (Liquid)

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	2.256E+01	3.898E-03	2.257E+01	2.515E-04	9.408E-05	0.0
0.0125	1.897E+01	3.927E-03	1.898E+01	3.728E-04	1.133E-04	0.0
0.0150	1.647E+01	3.944E-03	1.647E+01	5.147E-04	1.316E-04	0.0
0.0175	1.461E+01	3.955E-03	1.461E+01	6.761E-04	1.492E-04	0.0
0.0200	1.317E+01	3.963E-03	1.318E+01	8.566E-04	1.663E-04	0.0
0.0250	1.109E+01	3.974E-03	1.110E+01	1.272E-03	1.990E-04	0.0
0.0300	9.653E+00	3.984E-03	9.697E+00	1.756E-03	2.301E-04	0.0
0.0350	8.592E+00	3.994E-03	8.596E+00	2.306E-03	2.599E-04	0.0
0.0400	7.777E+00	4.005E-03	7.781E+00	2.919E-03	2.886E-04	0.0
0.0450	7.130E+00	4.018E-03	7.134E+00	3.591E-03	3.165E-04	0.0
0.0500	6.603E+00	4.031E-03	6.607E+00	4.320E-03	3.435E-04	0.0
0.0550	6.166E+00	4.046E-03	6.170E+00	5.103E-03	3.698E-04	0.0
0.0600	5.797E+00	4.062E-03	5.801E+00	5.940E-03	3.955E-04	0.0
0.0700	5.207E+00	4.098E-03	5.211E+00	7.762E-03	4.452E-04	0.0
0.0800	4.757E+00	4.138E-03	4.762E+00	9.773E-03	4.931E-04	0.0
0.0900	4.402E+00	4.181E-03	4.407E+00	1.196E-02	5.393E-04	0.0
0.1000	4.115E+00	4.228E-03	4.120E+00	1.431E-02	5.841E-04	0.0
0.1250	3.591E+00	4.355E-03	3.596E+00	2.083E-02	6.912E-04	0.0
0.1500	3.238E+00	4.494E-03	3.242E+00	2.817E-02	7.926E-04	0.0
0.1750	2.984E+00	4.643E-03	2.988E+00	3.622E-02	8.894E-04	0.0
0.2000	2.793E+00	4.801E-03	2.798E+00	4.487E-02	9.826E-04	0.0
0.2500	2.528E+00	5.141E-03	2.533E+00	6.372E-02	1.161E-03	0.0
0.3000	2.355E+00	5.514E-03	2.360E+00	8.421E-02	1.331E-03	0.0
0.3500	2.235E+00	5.913E-03	2.241E+00	1.060E-01	1.496E-03	0.0
0.4000	2.148E+00	6.339E-03	2.154E+00	1.288E-01	1.658E-03	0.0
0.4500	2.083E+00	6.787E-03	2.090E+00	1.523E-01	1.818E-03	0.0
0.5000	2.034E+00	7.257E-03	2.041E+00	1.766E-01	1.976E-03	0.0
0.5500	1.995E+00	7.747E-03	2.003E+00	2.013E-01	2.134E-03	1.103E-02
0.6000	1.963E+00	8.254E-03	1.972E+00	2.265E-01	2.292E-03	2.938E-02
0.7000	1.917E+00	9.312E-03	1.926E+00	2.778E-01	2.608E-03	7.435E-02
0.8000	1.886E+00	1.043E-02	1.896E+00	3.302E-01	2.928E-03	1.267E-01
0.9000	1.864E+00	1.159E-02	1.876E+00	3.832E-01	3.251E-03	1.835E-01
1.0000	1.849E+00	1.280E-02	1.862E+00	4.367E-01	3.579E-03	2.428E-01
1.2500	1.829E+00	1.600E-02	1.845E+00	5.717E-01	4.416E-03	3.944E-01
1.5000	1.822E+00	1.942E-02	1.841E+00	7.075E-01	5.281E-03	5.437E-01
1.7500	1.821E+00	2.303E-02	1.844E+00	8.432E-01	6.171E-03	6.866E-01
2.0000	1.824E+00	2.678E-02	1.850E+00	9.785E-01	7.085E-03	8.218E-01
2.5000	1.834E+00	3.468E-02	1.868E+00	1.247E+00	8.969E-03	1.069E+00
3.0000	1.846E+00	4.299E-02	1.889E+00	1.514E+00	1.092E-02	1.288E+00
3.5000	1.858E+00	5.164E-02	1.910E+00	1.777E+00	1.291E-02	1.484E+00
4.0000	1.870E+00	6.058E-02	1.931E+00	2.037E+00	1.495E-02	1.660E+00
4.5000	1.882E+00	6.976E-02	1.951E+00	2.295E+00	1.702E-02	1.821E+00
5.0000	1.892E+00	7.917E-02	1.971E+00	2.550E+00	1.911E-02	1.967E+00
5.5000	1.902E+00	8.876E-02	1.991E+00	2.802E+00	2.123E-02	2.102E+00
6.0000	1.911E+00	9.854E-02	2.010E+00	3.052E+00	2.336E-02	2.227E+00
7.0000	1.928E+00	1.185E-01	2.047E+00	3.545E+00	2.766E-02	2.453E+00
8.0000	1.943E+00	1.391E-01	2.082E+00	4.030E+00	3.200E-02	2.652E+00
9.0000	1.956E+00	1.601E-01	2.116E+00	4.506E+00	3.636E-02	2.831E+00
10.0000	1.968E+00	1.814E-01	2.149E+00	4.975E+00	4.072E-02	2.992E+00
12.5000	1.993E+00	2.362E-01	2.230E+00	6.117E+00	5.163E-02	3.341E+00
15.0000	2.014E+00	2.926E-01	2.306E+00	7.219E+00	6.243E-02	3.633E+00
17.5000	2.031E+00	3.501E-01	2.381E+00	8.286E+00	7.309E-02	3.885E+00
20.0000	2.046E+00	4.086E-01	2.454E+00	9.320E+00	8.355E-02	4.107E+00
25.0000	2.070E+00	5.277E-01	2.598E+00	1.130E+01	1.039E-01	4.487E+00
30.0000	2.089E+00	6.489E-01	2.738E+00	1.317E+01	1.233E-01	4.806E+00
35.0000	2.105E+00	7.716E-01	2.876E+00	1.496E+01	1.418E-01	5.082E+00
40.0000	2.118E+00	8.955E-01	3.013E+00	1.665E+01	1.594E-01	5.326E+00
45.0000	2.129E+00	1.021E+00	3.150E+00	1.828E+01	1.762E-01	5.544E+00
50.0000	2.139E+00	1.146E+00	3.286E+00	1.983E+01	1.923E-01	5.741E+00
55.0000	2.148E+00	1.273E+00	3.421E+00	2.132E+01	2.076E-01	5.921E+00
60.0000	2.156E+00	1.400E+00	3.556E+00	2.276E+01	2.222E-01	6.087E+00
70.0000	2.170E+00	1.656E+00	3.827E+00	2.547E+01	2.496E-01	6.383E+00
80.0000	2.182E+00	1.914E+00	4.096E+00	2.799E+01	2.747E-01	6.641E+00
90.0000	2.193E+00	2.173E+00	4.366E+00	3.035E+01	2.978E-01	6.871E+00

Polystyrene

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	2.223E+01	2.982E-03	2.224E+01	2.546E-04	7.406E-05	0.0
0.0125	1.868E+01	2.992E-03	1.869E+01	3.777E-04	8.869E-05	0.0
0.0150	1.621E+01	2.999E-03	1.621E+01	5.218E-04	1.027E-04	0.0
0.0175	1.437E+01	3.004E-03	1.438E+01	6.859E-04	1.162E-04	0.0
0.0200	1.296E+01	3.008E-03	1.296E+01	8.694E-04	1.292E-04	0.0
0.0250	1.091E+01	3.017E-03	1.091E+01	1.292E-03	1.543E-04	0.0
0.0300	9.485E+00	3.027E-03	9.488E+00	1.785E-03	1.782E-04	0.0
0.0350	8.440E+00	3.037E-03	8.443E+00	2.345E-03	2.013E-04	0.0
0.0400	7.637E+00	3.048E-03	7.640E+00	2.968E-03	2.235E-04	0.0
0.0450	7.000E+00	3.061E-03	7.003E+00	3.653E-03	2.452E-04	0.0
0.0500	6.481E+00	3.074E-03	6.484E+00	4.395E-03	2.662E-04	0.0
0.0550	6.051E+00	3.088E-03	6.054E+00	5.194E-03	2.867E-04	0.0
0.0600	5.688E+00	3.103E-03	5.691E+00	6.047E-03	3.068E-04	0.0
0.0700	5.108E+00	3.135E-03	5.111E+00	7.905E-03	3.458E-04	0.0
0.0800	4.666E+00	3.169E-03	4.669E+00	9.935E-03	3.834E-04	0.0
0.0900	4.317E+00	3.206E-03	4.320E+00	1.218E-02	4.197E-04	0.0
0.1000	4.034E+00	3.244E-03	4.038E+00	1.458E-02	4.550E-04	0.0
0.1250	3.520E+00	3.350E-03	3.523E+00	2.124E-02	5.396E-04	0.0
0.1500	3.172E+00	3.463E-03	3.176E+00	2.873E-02	6.199E-04	0.0
0.1750	2.923E+00	3.584E-03	2.926E+00	3.695E-02	6.967E-04	0.0
0.2000	2.735E+00	3.711E-03	2.739E+00	4.579E-02	7.709E-04	0.0
0.2500	2.475E+00	3.985E-03	2.479E+00	6.504E-02	9.131E-04	0.0
0.3000	2.305E+00	4.284E-03	2.309E+00	8.598E-02	1.050E-03	0.0
0.3500	2.187E+00	4.604E-03	2.192E+00	1.082E-01	1.182E-03	0.0
0.4000	2.101E+00	4.945E-03	2.106E+00	1.315E-01	1.312E-03	2.729E-05
0.4500	2.035E+00	5.304E-03	2.040E+00	1.557E-01	1.441E-03	2.688E-02
0.5000	1.984E+00	5.680E-03	1.990E+00	1.805E-01	1.570E-03	5.420E-02
0.5500	1.943E+00	6.071E-03	1.950E+00	2.059E-01	1.699E-03	8.383E-02
0.6000	1.911E+00	6.475E-03	1.918E+00	2.318E-01	1.827E-03	1.152E-01
0.7000	1.864E+00	7.322E-03	1.871E+00	2.846E-01	2.087E-03	1.810E-01
0.8000	1.832E+00	8.212E-03	1.840E+00	3.385E-01	2.349E-03	2.492E-01
0.9000	1.810E+00	9.142E-03	1.819E+00	3.932E-01	2.615E-03	3.179E-01
1.0000	1.794E+00	1.011E-02	1.804E+00	4.484E-01	2.885E-03	3.862E-01
1.2500	1.773E+00	1.267E-02	1.786E+00	5.878E-01	3.577E-03	5.515E-01
1.5000	1.766E+00	1.541E-02	1.781E+00	7.281E-01	4.293E-03	7.064E-01
1.7500	1.765E+00	1.830E-02	1.783E+00	8.684E-01	5.030E-03	8.501E-01
2.0000	1.768E+00	2.132E-02	1.789E+00	1.008E+00	5.788E-03	9.834E-01
2.5000	1.778E+00	2.766E-02	1.806E+00	1.287E+00	7.352E-03	1.222E+00
3.0000	1.791E+00	3.435E-02	1.825E+00	1.562E+00	8.970E-03	1.431E+00
3.5000	1.804E+00	4.132E-02	1.845E+00	1.835E+00	1.063E-02	1.616E+00
4.0000	1.816E+00	4.852E-02	1.865E+00	2.104E+00	1.233E-02	1.782E+00
4.5000	1.828E+00	5.593E-02	1.884E+00	2.371E+00	1.405E-02	1.932E+00
5.0000	1.839E+00	6.353E-02	1.902E+00	2.635E+00	1.580E-02	2.070E+00
5.5000	1.849E+00	7.129E-02	1.920E+00	2.897E+00	1.757E-02	2.197E+00
6.0000	1.859E+00	7.919E-02	1.938E+00	3.156E+00	1.936E-02	2.316E+00
7.0000	1.876E+00	9.539E-02	1.971E+00	3.667E+00	2.297E-02	2.531E+00
8.0000	1.891E+00	1.120E-01	2.003E+00	4.171E+00	2.662E-02	2.722E+00
9.0000	1.904E+00	1.290E-01	2.033E+00	4.666E+00	3.029E-02	2.896E+00
10.0000	1.916E+00	1.464E-01	2.062E+00	5.155E+00	3.399E-02	3.054E+00
12.5000	1.940E+00	1.909E-01	2.131E+00	6.347E+00	4.325E-02	3.403E+00
15.0000	1.960E+00	2.367E-01	2.196E+00	7.502E+00	5.249E-02	3.702E+00
17.5000	1.975E+00	2.835E-01	2.259E+00	8.625E+00	6.166E-02	3.963E+00
20.0000	1.989E+00	3.311E-01	2.320E+00	9.717E+00	7.072E-02	4.196E+00
25.0000	2.010E+00	4.282E-01	2.439E+00	1.182E+01	8.844E-02	4.596E+00
30.0000	2.027E+00	5.270E-01	2.554E+00	1.382E+01	1.056E-01	4.933E+00
35.0000	2.041E+00	6.271E-01	2.669E+00	1.574E+01	1.220E-01	5.225E+00
40.0000	2.053E+00	7.284E-01	2.782E+00	1.757E+01	1.378E-01	5.478E+00
45.0000	2.064E+00	8.306E-01	2.894E+00	1.933E+01	1.530E-01	5.704E+00
50.0000	2.073E+00	9.334E-01	3.006E+00	2.103E+01	1.676E-01	5.908E+00
55.0000	2.081E+00	1.037E+00	3.118E+00	2.266E+01	1.816E-01	6.093E+00
60.0000	2.089E+00	1.141E+00	3.230E+00	2.424E+01	1.951E-01	6.263E+00
70.0000	2.102E+00	1.351E+00	3.452E+00	2.723E+01	2.204E-01	6.565E+00
80.0000	2.113E+00	1.562E+00	3.675E+00	3.004E+01	2.439E-01	6.828E+00
90.0000	2.123E+00	1.774E+00	3.897E+00	3.268E+01	2.658E-01	7.060E+00

Teflon

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	1.843E+01	4.211E-03	1.843E+01	3.105E-04	1.249E-04	0.0
0.0125	1.553E+01	4.247E-03	1.554E+01	4.589E-04	1.502E-04	0.0
0.0150	1.351E+01	4.271E-03	1.351E+01	6.320E-04	1.743E-04	0.0
0.0175	1.200E+01	4.287E-03	1.201E+01	8.287E-04	1.975E-04	0.0
0.0200	1.084E+01	4.300E-03	1.084E+01	1.048E-03	2.199E-04	0.0
0.0250	9.141E+00	4.316E-03	9.146E+00	1.553E-03	2.629E-04	0.0
0.0300	7.965E+00	4.329E-03	7.970E+00	2.140E-03	3.037E-04	0.0
0.0350	7.098E+00	4.341E-03	7.102E+00	2.806E-03	3.428E-04	0.0
0.0400	6.430E+00	4.353E-03	6.435E+00	3.547E-03	3.805E-04	0.0
0.0450	5.900E+00	4.366E-03	5.904E+00	4.359E-03	4.169E-04	0.0
0.0500	5.468E+00	4.380E-03	5.472E+00	5.239E-03	4.522E-04	0.0
0.0550	5.109E+00	4.395E-03	5.113E+00	6.185E-03	4.865E-04	0.0
0.0600	4.806E+00	4.410E-03	4.810E+00	7.194E-03	5.200E-04	0.0
0.0700	4.321E+00	4.444E-03	4.325E+00	9.391E-03	5.847E-04	0.0
0.0800	3.951E+00	4.483E-03	3.955E+00	1.181E-02	6.467E-04	0.0
0.0900	3.658E+00	4.525E-03	3.663E+00	1.444E-02	7.065E-04	0.0
0.1000	3.421E+00	4.571E-03	3.426E+00	1.727E-02	7.643E-04	0.0
0.1250	2.989E+00	4.700E-03	2.994E+00	2.511E-02	9.021E-04	0.0
0.1500	2.697E+00	4.844E-03	2.702E+00	3.392E-02	1.032E-03	0.0
0.1750	2.487E+00	5.000E-03	2.492E+00	4.357E-02	1.156E-03	0.0
0.2000	2.330E+00	5.167E-03	2.335E+00	5.395E-02	1.275E-03	0.0
0.2500	2.111E+00	5.530E-03	2.117E+00	7.651E-02	1.503E-03	0.0
0.3000	1.968E+00	5.928E-03	1.974E+00	1.010E-01	1.721E-03	0.0
0.3500	1.869E+00	6.353E-03	1.875E+00	1.271E-01	1.931E-03	0.0
0.4000	1.797E+00	6.803E-03	1.804E+00	1.543E-01	2.137E-03	2.294E-03
0.4500	1.742E+00	7.279E-03	1.749E+00	1.824E-01	2.341E-03	2.338E-02
0.5000	1.699E+00	7.775E-03	1.707E+00	2.114E-01	2.543E-03	4.753E-02
0.5500	1.665E+00	8.291E-03	1.674E+00	2.410E-01	2.744E-03	7.398E-02
0.6000	1.639E+00	8.823E-03	1.647E+00	2.711E-01	2.945E-03	1.022E-01
0.7000	1.600E+00	9.937E-03	1.610E+00	3.326E-01	3.347E-03	1.623E-01
0.8000	1.573E+00	1.111E-02	1.585E+00	3.952E-01	3.753E-03	2.253E-01
0.9000	1.555E+00	1.233E-02	1.568E+00	4.587E-01	4.162E-03	2.896E-01
1.0000	1.543E+00	1.360E-02	1.557E+00	5.227E-01	4.575E-03	3.541E-01
1.2500	1.527E+00	1.697E-02	1.544E+00	6.841E-01	5.631E-03	5.127E-01
1.5000	1.522E+00	2.057E-02	1.542E+00	8.462E-01	6.719E-03	6.637E-01
1.7500	1.522E+00	2.437E-02	1.546E+00	1.008E+00	7.837E-03	8.056E-01
2.0000	1.525E+00	2.834E-02	1.553E+00	1.169E+00	8.983E-03	9.382E-01
2.5000	1.535E+00	3.667E-02	1.572E+00	1.490E+00	1.134E-02	1.178E+00
3.0000	1.546E+00	4.544E-02	1.592E+00	1.806E+00	1.377E-02	1.390E+00
3.5000	1.558E+00	5.456E-02	1.612E+00	2.118E+00	1.626E-02	1.578E+00
4.0000	1.569E+00	6.399E-02	1.633E+00	2.426E+00	1.879E-02	1.748E+00
4.5000	1.579E+00	7.367E-02	1.653E+00	2.730E+00	2.136E-02	1.902E+00
5.0000	1.589E+00	8.357E-02	1.672E+00	3.031E+00	2.395E-02	2.043E+00
5.5000	1.598E+00	9.367E-02	1.692E+00	3.328E+00	2.656E-02	2.173E+00
6.0000	1.606E+00	1.040E-01	1.710E+00	3.622E+00	2.919E-02	2.294E+00
7.0000	1.621E+00	1.250E-01	1.746E+00	4.201E+00	3.447E-02	2.512E+00
8.0000	1.635E+00	1.466E-01	1.781E+00	4.768E+00	3.978E-02	2.706E+00
9.0000	1.646E+00	1.686E-01	1.815E+00	5.324E+00	4.509E-02	2.880E+00
10.0000	1.657E+00	1.910E-01	1.848E+00	5.870E+00	5.040E-02	3.039E+00
12.5000	1.679E+00	2.483E-01	1.927E+00	7.194E+00	6.355E-02	3.385E+00
15.0000	1.697E+00	3.071E-01	2.004E+00	8.466E+00	7.648E-02	3.677E+00
17.5000	1.712E+00	3.672E-01	2.079E+00	9.691E+00	8.913E-02	3.930E+00
20.0000	1.724E+00	4.281E-01	2.152E+00	1.087E+01	1.015E-01	4.155E+00
25.0000	1.745E+00	5.521E-01	2.297E+00	1.312E+01	1.252E-01	4.541E+00
30.0000	1.761E+00	6.781E-01	2.439E+00	1.523E+01	1.476E-01	4.866E+00
35.0000	1.774E+00	8.056E-01	2.579E+00	1.723E+01	1.687E-01	5.146E+00
40.0000	1.785E+00	9.344E-01	2.719E+00	1.911E+01	1.886E-01	5.394E+00
45.0000	1.795E+00	1.064E+00	2.859E+00	2.091E+01	2.075E-01	5.614E+00
50.0000	1.803E+00	1.195E+00	2.998E+00	2.262E+01	2.253E-01	5.814E+00
55.0000	1.811E+00	1.326E+00	3.137E+00	2.425E+01	2.421E-01	5.996E+00
60.0000	1.818E+00	1.458E+00	3.276E+00	2.580E+01	2.581E-01	6.163E+00
70.0000	1.830E+00	1.724E+00	3.554E+00	2.874E+01	2.878E-01	6.461E+00
80.0000	1.840E+00	1.991E+00	3.831E+00	3.144E+01	3.147E-01	6.721E+00
90.0000	1.849E+00	2.260E+00	4.109E+00	3.396E+01	3.392E-01	6.952E+00