
UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2004/2005

October 2004

ZCT 533/4 - Dosimetry and Radiation Protection
[Dosimetri dan Perlindungan Sinaran]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **TWENTY ONE** pages of printed material before you begin the examination.

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

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

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

1. (a) Explain the differences between fluence and energy fluence.
 [(a) *Jelaskan perbezaan di antara fluens dan fluens tenaga.*] (6/20)
- (b) A narrow γ -ray beam passes through a 2-cm thick lead . The incident beam consists of 30% 0.4 MeV photons and 70% 1.5 MeV photons.
 [(b) *Suatu alur sempit sinar- γ melalui suatu kepingan plumbum berketebalan 2 cm . Alur tuju terdiri daripada 30% foton 0.4 MeV dan 70% foton 1.5 MeV.*]
 (i) Calculate the fraction of the incident fluence which is transmitted through lead.
 [(i) *Hitung pecahan fluens tuju yang ditransmisikan melalui plumbum.*]
 (ii) Calculate the fraction of the incident energy fluence which is transmitted through lead.
 [(ii) *Hitung pecahan fluens tenaga tuju yang ditransmisikan melalui plumbum.*]
 (14/20)
2. (a) Discuss the differences between energy transfer and net energy transfer in a volume V .
 [(a) *Bincangkan perbezaan di antara pemindahan tenaga dengan pemindahan tenaga berkesan dalam suatu isipadu V .*] (5/20)
- (b) Explain the meaning of kerma and absorbed dose. Describe how they are related to each other.
 [(b) *Jelaskan maksud kerma dan dos terserap. Huraikan perhubungan keduanya.*] (5/20)
- (c) A photon beam of energy 5 MeV and fluence 10^{14} m^{-2} is incident on a point P in an aluminium block. Calculate the kerma and the absorbed dose at point P.
 [(c) *Suatu alur foton bertenaga 5 MeV dan fluens 10^{14} m^{-2} tertuju pada suatu titik P dalam suatu bongkah aluminium. Hitung kerma dan dos terserap pada titik P.]*
 If an ion chamber containing 1 cm^3 air is placed at point P, calculate the number of ion pairs produced.
 [Jika suatu kebuk ion mangandungi 1 cm^3 udara diletakkan pada titik P, hitung bilangan pasangan ion yang dihasilkan.]
 (Assume the density of air is 1.293 kg m^{-3} .)
 [(Anggap ketumpatan udara ialah 1.293 kg m^{-3} .)]
 (10/20)

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3. (a) Describe the Bragg-Gray cavity theory. State the assumptions of the theory.
 [(a) *Perihalkan teori rongga Bragg-Gray. Nyatakan anggapan-anggapan teori ini.*]
 (6/20)
- (b) Describe the major differences between the Bragg-Gray cavity theory and the Burlin cavity theory.
 [(b) *Perihalkan perbezaan-perbezaan utama di antara teori rongga Bragg-Gray dan teori rongga Burlin.*]
 (4/20)
- (c) A beam of electrons passes through a tin foil. The kinetic energy of the incident electrons is 7 MeV and its fluence is 10^{10} cm^{-2} . The mass thickness of the foil is 0.73 g cm^{-2} . Given that the increase in the electron pathlength in the foil is 7%. Assume that any photons produced escape.
 [(c) *Suatu alur elektron melalui suatu kerajang timah. Tenaga kinetik elektron tuju ialah 7 MeV dan fluensnya ialah 10^{10} cm^{-2} . Ketebalan jisim kerajang ialah 0.73 g cm^{-2} . Diberikan penambahan panjang lintasan elektron ialah 7%. Anggap sebarang foton yang dihasilkan terlepas.*]
 (i) Calculate the kinetic energy of the exiting electrons.
 [(i) *Hitung tenaga kinetik elektron yang keluar.*]
 (ii) Determine the absorbed dose in the foil.
 [(ii) *Tentukan dos terserap dalam kerajang.*]
 (iii) If the thickness of the foil is increased so that no electron exits the foil, determine the new absorbed dose.
 [(iii) *Jika ketebalan kerajang ditambah agar tiada elektron yang terkeluar, tentukan dos terserap yang baru.*]
 (10/20)
4. (a) Describe the construction of a standard free-air ion chamber. State why it is not used at potentials greater than 300 kV.
 [(a) *Perihalkan binaan suatu kebuk ion udara bebas piawai. Nyatakan mengapa ia tidak digunakan pada keupayaan lebih besar daripada 300 kV.*]
 (5/20)
- (b) Discuss why the exposure calibration factor N_x cannot be calculated for ion chambers routinely used in hospitals/laboratory for dose measurements. How is N_x normally obtained?
 [(b) *Bincangkan mengapa faktor tentukuran dedahan N_x tidak boleh dihitung bagi kebuk ion yang lazimnya digunakan di hospital/makmal untuk pengukuran dos. Bagaimanakah N_x biasanya diperolehi?*]
 (4/20)

- (c) Describe how a Fricke ferrous sulphate dosimeter is used to measure absorbed dose.
 [(c) *Perihalkan bagaimana meterdos Fricke ferrous sulphate digunakan untuk mengukur dos.*]
 (5/20)
- (d) Describe how a thermoluminescence (TL) process occurs. Show the dependence of relative TL reading per unit exposure on energy between 20 keV to 1 MeV for CaF₂ TLD. Explain.
 [(d) *Perihalkan bagaimana proses pendarkilau haba (TL) berlaku. Tunjukkan kesandaran bacaan TL relatif per unit dedahan kepada tenaga di antara 20 keV hingga 1 MeV bagi meterdos pendarkilau haba CaF₂. Jelaskan.*]
 (6/20)
5. (a) Give the meaning of stochastic and non-stochastic quantities. Give examples for each type of quantity.
 [(a) *Berikan maksud kuantiti stokastik dan kuantiti bukan stokastik. Berikan contoh-contoh bagi setiap jenis kuantiti.*]
 (5/20)
- (b) Describe the differences between the somatic effect and the genetic effect. Give examples for each of them.
 [(b) *Perihalkan perbezaan di antara kesan somatik dengan kesan genetik. Berikan contoh-contoh bagi setiapnya.*]
 (5/20)
- (c) Explain the oxygen effect in radiobiology.
 [(c) *Jelaskan kesan oxygen dalam radiobiologi.*]
 (4/20)
- (d) Discuss the models used to determine cancer risk in the low dose region. State its importance in radiation protection.
 [(d) *Bincangkan model-model yang digunakan untuk menentukan risiko barah dalam rantau dos rendah. Nyatakan kepentingannya dalam perlindungan sinaran.*]
 (6/20)

APPENDIXES

APPENDIX A.1. Physical Constants

Quantity	Symbol	Value
Speed of light in vacuum	c	$2.9979 \times 10^8 \text{ m s}^{-1}$
Elementary charge	e	$1.6022 \times 10^{-19} \text{ C}$ $= 4.8032 \times 10^{-10} \text{ esu}$
Planck constant	h	$6.6262 \times 10^{-34} \text{ J H}$
Avogadro constant	N_A	$6.0220 \times 10^{23} \text{ mole}^{-1}$
Atomic mass unit	$1 \text{ u} = (10^{-3} \text{ kg mole}^{-1})/N_A$	$1.6606 \times 10^{-27} \text{ kg}$
Electron rest mass	m_0	$0.91095 \times 10^{-30} \text{ kg}$
Proton rest mass	$(M_0)_p$	$1.6726 \times 10^{-27} \text{ kg}$
Neutron rest mass	$(M_0)_n$	$1.6750 \times 10^{-27} \text{ kg}$
Ratio, proton mass to electron mass	$(M_0)_p/m_0$	1836
Classical electron radius	r_e	$2.8179 \times 10^{-15} \text{ m}$
Molar gas constant	R	$8.3144 \text{ J mole}^{-1} \text{ K}^{-1}$
Molar volume, ideal gas ($T_0 = 273.15 \text{ K}$, $p_0 = 1 \text{ atm}$)	$V_m = RT_0/P_0$	$0.022414 \text{ m}^3 \text{ mole}^{-1}$
Boltzmann constant	$k = R/N_A$	$1.3807 \times 10^{-23} \text{ J K}^{-1}$

APPENDIX A.2. Conversion Factors

$1 \text{ kg} = 5.6095 \times 10^{21} \text{ MeV}$
$1 \text{ amu} = 931.50 \text{ MeV}$
Electron rest mass = 0.51100 MeV
Proton rest mass = 938.26 MeV
Neutron rest mass = 939.55 MeV
1 electron volt (eV) = $1.6022 \times 10^{-19} \text{ J}$ $= 1.6022 \times 10^{-12} \text{ erg}$
1 joule (J) = 10^7 erg
1 coulomb (C) = $2.9979 \times 10^9 \text{ esu}$
1 gray (Gy) = $1 \text{ J/kg} = 10^2 \text{ rad} = 10^4 \text{ erg/g}$
1 sievert (Sv) = 1 J/kg
Energy-wavelength conversion:
$1.23985 \times 10^{-6} \text{ eV m}$
12.3985 keV \AA
Exposure conversion:
1 roentgen (R) = $2.58 \times 10^{-4} \text{ C/kg}$
1 C/kg = 3876 R

APPENDIX B.1. Data Table of the Elements

Element	Symbol	At. No. Z	At. Wt. A	Z/A	$10^{-23} N_A Z/A^2$	Density ^b (g/cm ³)	K-edge (keV)	L1-edge (keV)	I' (eV)
Hydrogen	H	1	1.008	.9922	5.975	8.374×10^{-3}	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	$10^{-23} N_A Z/A^2$	Density ^b (g/cm ³)	K-edge (keV)	L1-edge (keV)	I' (eV)
Copper	Cu	29	63.55	.4564	2.748	8.94	8.98	1.10	322
Zinc	Zn	30	65.38	.4589	2.763	7.11	9.66	1.19	330
Gallium	Ga	31	69.72	.4446	2.678	5.88	10.38	1.30	—
Germanium	Ge	32	72.59	.4408	2.655	5.31	11.10	1.41	350
Arsenic	As	33	74.92	.4405	2.652	5.73	11.87	1.53	—
Selenium	Se	34	78.96	.4306	2.593	4.28, 4.79	12.66	1.65	348
Bromine	Br	35	79.90	.4380	2.638	7.07×10^{-3}	13.47	1.78	—
Krypton	Kr	36	83.80	.4296	2.587	3.478×10^{-3}	14.33	1.92	352
Rubidium	Rb	37	85.47	.4329	2.607	1.529	15.20	2.07	363
Strontium	Sr	38	87.62	.4337	2.612	2.54	16.10	2.22	—
Yttrium	Y	39	88.91	.4387	2.642	4.46	17.04	2.37	—
Zirconium	Zr	40	91.22	.4385	2.641	6.49	18.00	2.53	—
Niobium	Nb	41	92.91	.4413	2.658	8.55	18.99	2.70	—
Molybdenum	Mo	42	95.94	.4378	2.636	10.20	20.00	2.87	—
Technetium	Tc	43	98.91	.4348	2.618	11.50	21.04	3.04	—
Ruthenium	Ru	44	101.1	.4353	2.622	12.41	22.12	3.22	—
Rhodium	Rh	45	102.9	.4373	2.633	12.41	23.22	3.41	—
Palladium	Pd	46	106.4	.4323	2.604	12.00	24.35	3.60	—
Silver	Ag	47	107.9	.4357	2.624	10.48	25.51	3.81	470
Cadmium	Cd	48	112.4	.4270	2.571	8.65	26.71	4.02	469
Indium	In	49	114.8	.4268	2.570	7.30	27.94	4.24	487
Tin (white)	Sn	50	118.7	.4213	2.537	7.31	29.20	4.46	488
Antimony	Sb	51	121.7	.4191	2.524	6.68	30.5	4.70	—
Tellurium	Te	52	127.6	.4075	2.454	6.23	31.8	4.94	—
Iodine	I	53	126.9	.4176	2.515	4.92	33.2	5.19	—
Xenon	Xe	54	131.3	.4113	2.477	5.485×10^{-3}	34.6	5.45	482
Cesium	Cs	55	132.9	.4138	2.492	1.870	36.0	5.71	488
Barium	Ba	56	137.3	.4078	2.456	3.5	37.4	5.99	—

APPENDIX B.1. (Continued)

Element	Symbol	At. No. Z	At. Wt. A	Z/A	$10^{-23} N_A Z/A^2$	Density ^b (g/cm ³)	K-edge (keV)	L1-edge (keV)	I' (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.1. (Continued)

Element	Symbol	At. No. Z	At. Wt. A	Z/A	$10^{-23} N_e Z/A^2$	Density ^b (g/cm ³)	K-edge (keV)	L1-edge (keV)	I ^c (eV)
Astatine	At	85	(210)	.405	2.44	—	95.7	17.5	—
Radon	Rn	86	(222)	.387	2.33	9.07 × 10 ⁻³	98.4	18.0	794
Francium	Fr	87	(223)	.390	2.35	—	101.1	18.6	—
Radium	Ra	88	226.0	.3893	2.345	—	103.9	19.2	—
Actinium	Ac	89	(227)	.392	2.36	10.07	106.8	19.8	—
Thorium	Th	90	232.0	.3879	2.336	11.72	109.7	20.5	—
Protactinium	Pa	91	231.0	.3939	2.372	15.37	112.6	21.1	—
Uranium	U	92	238.0	.3865	2.328	18.95	115.6	21.8	890
Neptunium	Np	93	237.0	.3923	2.363	20.21	118.7	22.4	—
Plutonium	Pu	94	(244)	.385	2.32	19.78	121.8	23.1	—
Americium	Am	95	(243)	.391	2.35	13.65	125.0	23.8	—
Curium	Cm	96	(247)	.389	2.34	13.51	128.2	24.5	—
Berkelium	Bk	97	(247)	.393	2.36	≅ 14	131.6	25.3	—
Californium	Cf	98	(251)	.390	2.35	—	136.0	26.1	—
Einsteinium	Es	99	(254)	.390	2.35	—	139.5	26.9	—
Fermium	Fm	100	(257)	.389	2.34	—	143.1	27.7	—
Mendelevium	Md	101	(258)	.391	2.36	—	146.8	28.5	—
Nobelium	No	102	(259)	.394	2.37	—	150.5	29.4	—
Lawrencium	Lr	103	(260)	.396	2.39	—	154.4	30.2	—

^a Number of electrons per gram of element (in units of 10²³).

^b Assuming T = 20°C and P = 1 atm, and Charles's law for gases. Multiply by 10³ to convert to kg m⁻³.

^c From Berger and Seltzer (1983). I is the mean excitation potential for stopping power; see Chapter 8.

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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>I</i> (eV)
A-150 plastic ^b	1.127	3.306	65
Adipose tissue (Fat, ICRP) ^b	0.92	3.363	63
Air ^b	1.205 × 10 ⁻³	3.006	85
Bone, cortical (ICRP) ^b	1.85	3.139	106
Calcium fluoride, CaF ₂	3.18	2.931	166
Carbon dioxide, CO ₂	1.842 × 10 ⁻³	3.010	85
Cesium iodide, CsI	4.51	2.503	553
Lithium fluoride, LiF	2.64	2.786	94
Lucite, (C ₅ H ₈ O ₂) _n	1.19	3.248	74
Muscle, skeletal (ICRP) ^b	1.04	3.308	75
Mylar, (C ₁₀ H ₈ O ₄) _n	1.40	3.134	78
Nylon, type 6 (C ₆ H ₁₁ NO) _n	1.14	3.299	63
Polycarbonate (C ₁₆ H ₁₄ O ₃) _n	1.20	3.173	73
Polyethylene (C ₂ H ₄) _n	0.94	3.435	57
Polyimide (C ₂₂ H ₁₀ N ₂ O ₅) _n	1.42	3.087	79
Polypropylene (C ₃ H ₅) _n	0.90	3.372	59
Polystyrene (C ₈ H ₈) _n	1.06	3.238	68
Polyvinyl Chloride (C ₂ H ₃ Cl) _n	1.30	3.083	108
Pyrex (borosilicate glass) ^b	2.23	2.993	134
Silicon dioxide, SiO ₂	2.32	3.007	139
Silver bromide, AgBr	6.47	2.629	487
Sodium iodide, NaI	3.67	2.571	452
Teflon, (C ₂ F ₄) _n	2.20	2.890	99
TE gas (methane-based) ^b	1.064 × 10 ⁻³	3.312	61
TE gas (propane-based) ^b	1.826 × 10 ⁻³	3.314	59
TE liquid (no sucrose) ^b	1.070	3.313	74
Water, H ₂ O	0.9982	3.343	75

^aData from Berger and Seltzer (1983)

^bSee compositions in Appendix B.3

^cAssuming *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.2. (Continued)

Aluminum, Z = 13
 Multiply by 0.02232 to get cm²/g
 or by 0.002232 to get m²/kg

Photon Energy (MeV)	Compton With and Without Coherent		Photoelectric σ^T	Nuclear and Electron Pair		Total With and Without Coherent	
	$\sigma + \sigma_R$	σ		σ^{nuc}	σ^{elec}	μ	$\mu - \sigma_R$
1.00 -02	3.04 +01	8.32 +00	1.15 +03	—	—	1.18 +03	1.16 +03
1.50 -02	2.03 +01	8.17 +00	3.35 +02	—	—	3.55 +02	3.43 +02
2.00 -02	1.57 +01	8.03 +00	1.37 +02	—	—	1.53 +02	1.45 +02
3.00 -02	1.17 +01	7.77 +00	3.85 +01	—	—	5.02 +01	4.63 +01
4.00 -02	9.89 +00	7.52 +00	1.55 +01	—	—	2.54 +01	2.30 +01
5.00 -02	8.88 +00	7.30 +00	7.65 +00	—	—	1.65 +01	1.49 +01
6.00 -02	8.22 +00	7.09 +00	4.33 +00	—	—	1.25 +01	1.14 +01
8.00 -02	7.38 +00	6.72 +00	1.73 +00	—	—	9.11 +00	8.45 +00
1.00 -01	6.83 +00	6.41 +00	8.45 -01	—	—	7.67 +00	7.25 +00
1.50 -01	5.96 +00	5.77 +00	2.33 -01	—	—	6.19 +00	6.00 +00
2.00 -01	5.39 +00	5.28 +00	9.53 -02	—	—	5.49 +00	5.38 +00
3.00 -01	4.64 +00	4.60 +00	2.76 -02	—	—	4.67 +00	4.62 +00
4.00 -01	4.14 +00	4.12 +00	1.19 -02	—	—	4.15 +00	4.13 +00
5.00 -01	3.78 +00	3.76 +00	6.43 -03	—	—	3.78 +00	3.77 +00
6.00 -01	3.49 +00	3.48 +00	4.02 -03	—	—	3.49 +00	3.48 +00
8.00 -01	3.06 +00	3.06 +00	2.04 -03	—	—	3.06 +00	3.06 +00

1.00 +00	2.75 +00	2.75 +00	1.26 -03	—	—	2.75 +00	2.75 +00
1.50 +00	2.23 +00		5.89 -04	7.68 -03	—	2.24 +00	
2.00 +00	1.91 +00		3.73 -04	3.03 -02	—	1.94 +00	
3.00 +00	1.50 +00		2.07 -04	8.65 -02	5.23 -04	1.59 +00	
4.00 +00	1.25 +00		1.41 -04	1.40 -01	2.15 -03	1.39 +00	
5.00 +00	1.08 +00		1.07 -04	1.87 -01	4.22 -03	1.27 +00	
6.00 +00	9.54 -01		8.53 -05	2.29 -01	6.49 -03	1.19 +00	
8.00 +00	7.81 -01		6.09 -05	2.99 -01	1.11 -02	1.09 +00	
1.00 +01	6.65 -01		4.76 -05	3.57 -01	1.52 -02	1.04 +00	
1.50 +01	4.92 -01		—	4.65 -01	2.36 -02	9.80 -01	
2.00 +01	3.95 -01		—	5.43 -01	3.03 -02	9.68 -01	
3.00 +01	2.88 -01		—	6.52 -01	4.04 -02	9.81 -01	
4.00 +01	2.29 -01		—	7.29 -01	4.79 -02	1.01 +00	
5.00 +01	1.91 -01		—	7.86 -01	5.36 -02	1.03 +00	
6.00 +01	1.64 -01		—	8.31 -01	5.81 -02	1.05 +00	
8.00 +01	1.30 -01		—	8.98 -01	6.51 -02	1.09 +00	
1.00 +02	1.08 -01		—	9.46 -01	7.03 -02	1.12 +00	

APPENDIX D.2. (Continued)

Tin, Z = 50								
Multiply by 0.005074 to get cm ² /g or by 0.0005074 to get m ² /kg								
Photon Energy (MeV)	Compton With and Without Coherent		Photoelectric σ_T	Nuclear and Electron Pair		Total With and Without Coherent		
	$\sigma + \sigma_R$	σ		σ_{nuc}	σ_{elec}	σ_{μ}	$\sigma_{\mu} - \sigma_R$	
K	1.00 -02	5.38 +02	3.20 +01	2.73 +04	—	—	2.79 +04	2.74 +04
	1.50 -02	3.60 +02	3.14 +01	8.91 +03	—	—	9.27 +03	8.94 +03
	2.00 -02	2.59 +02	3.09 +01	3.95 +03	—	—	4.21 +03	3.98 +03
	2.92 -02	1.61 +02	2.99 +01	1.33 +03	—	—	1.49 +03	1.36 +03
	2.92 -02	1.61 +02	2.99 +01	8.57 +03	—	—	8.73 +03	8.60 +03
	3.00 -02	1.56 +02	2.99 +01	7.98 +03	—	—	8.14 +03	8.01 +03
	4.00 -02	1.10 +02	2.89 +01	3.70 +03	—	—	3.81 +03	3.73 +03
	5.00 -02	8.44 +01	2.81 +01	2.02 +03	—	—	2.10 +03	2.04 +03
	6.00 -02	6.85 +01	2.73 +01	1.22 +03	—	—	1.29 +03	1.25 +03
	8.00 -02	5.02 +01	2.59 +01	5.45 +02	—	—	5.95 +02	5.71 +02
	1.00 -01	4.05 +01	2.46 +01	2.90 +02	—	—	3.31 +02	3.15 +02
	1.50 -01	2.96 +01	2.22 +01	9.15 +01	—	—	1.21 +02	1.14 +02
	2.00 -01	2.45 +01	2.03 +01	4.02 +01	—	—	6.47 +01	6.06 +01
	3.00 -01	1.96 +01	1.77 +01	1.28 +01	—	—	3.24 +01	3.05 +01
	4.00 -01	1.69 +01	1.58 +01	5.93 +00	—	—	2.28 +01	2.18 +01
	5.00 -01	1.51 +01	1.45 +01	3.50 +00	—	—	1.86 +01	1.80 +01
	6.00 -01	1.39 +01	1.34 +01	2.20 +00	—	—	1.61 +01	1.56 +01
	8.00 -01	1.20 +01	1.18 +01	1.15 +00	—	—	1.32 +01	1.29 +01
	1.00 +00	1.07 +01	1.06 +01	6.90 -01	—	—	1.14 +01	1.13 +01
	1.50 +00	8.65 +00	8.59 +00	3.13 -01	1.53 -01	—	9.12 +00	9.06 +00
	2.00 +00	7.36 +00	7.33 +00	1.93 -01	5.23 -01	—	8.08 +00	8.04 +00
	3.00 +00	5.77 +00	5.77 +00	1.05 -01	1.35 +00	2.01 -03	7.24 +00	7.23 +00
	4.00 +00	4.82 +00	4.81 +00	6.93 -02	2.10 +00	8.26 -03	7.00 +00	6.98 +00
	5.00 +00	4.16 +00	4.15 +00	5.18 -02	2.74 +00	1.62 -02	6.97 +00	6.96 +00
	6.00 +00	3.68 +00	3.67 +00	4.05 -02	3.29 +00	2.50 -02	7.03 +00	7.03 +00
	8.00 +00	3.00 +00	—	2.83 -02	4.21 +00	4.27 -02	7.28 +00	—
	1.00 +01	2.56 +00	—	2.18 -02	4.95 +00	5.84 -02	7.58 +00	—
	1.50 +01	1.89 +00	—	1.37 -02	6.38 +00	9.09 -02	8.37 +00	—
	2.00 +01	1.52 +00	—	9.94 -03	7.44 +00	1.16 -01	9.08 +00	—
	3.00 +01	1.11 +00	—	6.41 -03	8.92 +00	1.52 -01	1.02 +01	—
	4.00 +01	8.79 -01	—	4.73 -03	9.92 +00	1.77 -01	1.10 +01	—
	5.00 +01	7.34 -01	—	3.75 -03	1.07 +01	1.96 -01	1.16 +01	—
	6.00 +01	6.32 -01	—	3.10 -03	1.12 +01	2.11 -01	1.21 +01	—
	8.00 +01	4.98 -01	—	2.31 -03	1.21 +01	2.35 -01	1.28 +01	—
	1.00 +02	4.14 -01	—	1.84 -03	1.27 +01	2.52 -01	1.33 +01	—

APPENDIX D.2. (Continued)

Lead, Z = 82
 Multiply by 0.002907 to get cm²/g
 or by 0.0002907 to get m²/kg

Photon Energy (MeV)	Compton With and Without Coherent		Photoelectric τ	Nuclear and Electron Pair		Total With and Without Coherent	
	$\sigma + \sigma_R$	σ		κ_{nuc}	κ_{elec}	μ	$\mu - \sigma_R$
L ₃ 1.00 -02	1.73 +03	5.25 +01	4.40 +04	—	—	4.57 +04	4.41 +04
1.30 -02	1.34 +03	5.19 +01	2.20 +04	—	—	2.33 +04	2.20 +04
1.30 -02	1.34 +03	5.19 +01	5.58 +04	—	—	5.71 +04	5.59 +04
1.50 -02	1.15 +03	5.16 +01	3.84 +04	—	—	3.96 +04	3.85 +04
1.52 -02	1.13 +03	5.15 +01	3.75 +04	—	—	3.86 +04	3.76 +04
L ₂ 1.52 -02	1.13 +03	5.15 +01	4.90 +04	—	—	5.01 +04	4.91 +04
1.59 -02	1.08 +03	5.14 +01	4.35 +04	—	—	4.46 +04	4.36 +04
L ₁ 1.59 -02	1.08 +03	5.14 +01	5.29 +04	—	—	5.40 +04	5.29 +04
2.00 -02	8.17 +02	5.07 +01	2.86 +04	—	—	2.95 +04	2.87 +04
3.00 -02	4.91 +02	4.90 +01	9.71 +03	—	—	1.02 +04	9.76 +03
4.00 -02	3.36 +02	4.75 +01	4.47 +03	—	—	4.81 +03	4.52 +03
5.00 -02	2.48 +02	4.60 +01	2.44 +03	—	—	2.68 +03	2.48 +03
6.00 -02	1.94 +02	4.47 +01	1.48 +03	—	—	1.67 +03	1.52 +03
8.00 -02	1.32 +02	4.24 +01	6.70 +02	—	—	8.03 +02	7.13 +02
K 8.80 -02	1.16 +02	4.16 +01	5.15 +02	—	—	6.31 +02	5.56 +02
8.80 -02	1.16 +02	4.16 +01	2.45 +03	—	—	2.56 +03	2.49 +03
1.00 -01	9.93 +01	4.04 +01	1.76 +03	—	—	1.86 +03	1.80 +03
1.50 -01	6.39 +01	3.64 +01	6.14 +02	—	—	6.78 +02	6.51 +02
2.00 -01	4.92 +01	3.33 +01	2.92 +02	—	—	3.41 +02	3.25 +02
3.00 -01	3.61 +01	2.90 +01	1.03 +02	—	—	1.39 +02	1.32 +02
4.00 -01	3.00 +01	2.60 +01	4.96 +01	—	—	7.96 +01	7.56 +01
5.00 -01	2.63 +01	2.37 +01	2.92 +01	—	—	5.55 +01	5.29 +01
6.00 -01	2.37 +01	2.19 +01	1.92 +01	—	—	4.29 +01	4.11 +01
8.00 -01	2.03 +01	1.93 +01	1.02 +01	—	—	3.04 +01	2.95 +01
1.00 +00	1.79 +01	1.73 +01	6.39 +00	—	—	2.43 +01	2.37 +01
1.50 +00	1.43 +01	1.41 +01	2.89 +00	5.66 -01	—	1.78 +01	1.75 +01
2.00 +00	1.22 +01	1.20 +01	1.77 +00	1.70 +00	—	1.57 +01	1.55 +01
3.00 +00	9.51 +00	9.46 +00	9.14 -01	3.94 +00	3.30 -03	1.44 +01	1.43 +01
4.00 +00	7.94 +00	7.89 +00	5.89 -01	5.77 +00	1.35 -02	1.43 +01	1.43 +01
5.00 +00	6.84 +00	6.81 +00	4.34 -01	7.30 +00	2.66 -02	1.46 +01	1.46 +01
6.00 +00	6.04 +00	6.02 +00	3.36 -01	8.54 +00	4.09 -02	1.50 +01	1.49 +01
8.00 +00	4.93 +00	4.92 +00	2.31 -01	1.05 +01	7.00 -02	1.58 +01	1.58 +01
1.00 +01	4.20 +00	4.19 +00	1.78 -01	1.22 +01	9.57 -02	1.67 +01	1.67 +01
1.50 +01	3.10 +00	—	1.12 -01	1.55 +01	1.48 -01	1.89 +01	—
2.00 +01	2.49 +00	—	8.10 -02	1.81 +01	1.86 -01	2.09 +01	—
3.00 +01	1.81 +00	—	5.20 -02	2.18 +01	2.42 -01	2.39 +01	—
4.00 +01	1.44 +00	—	3.80 -02	2.43 +01	2.81 -01	2.60 +01	—
5.00 +01	1.20 +00	—	3.00 -02	2.61 +01	3.11 -01	2.77 +01	—
6.00 +01	1.04 +00	—	2.50 -02	2.75 +01	3.35 -01	2.89 +01	—
8.00 +01	8.18 -01	—	1.80 -02	2.96 +01	3.71 -01	3.06 +01	—
1.00 +02	6.79 -01	—	1.41 -02	3.10 +01	3.97 -01	3.21 +01	—

...13/-

APPENDIX D.3. (Continued)

Photon Energy (MeV)	Air			Water			ICRU Compact Bone			ICRU Striated Muscle		
	μ/ρ	μ_{en}/ρ	μ_{cl}/ρ	μ/ρ	μ_{en}/ρ	μ_{cl}/ρ	μ/ρ	μ_{en}/ρ	μ_{cl}/ρ	μ/ρ	μ_{en}/ρ	μ_{cl}/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
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_{en}/ρ	μ_{cl}/ρ	μ/ρ	μ_{en}/ρ	μ_{cl}/ρ	μ/ρ	μ_{en}/ρ	μ_{cl}/ρ	μ/ρ	μ_{en}/ρ	μ_{cl}/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
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

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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

^aData for Li, F, LiF, and Teflon are taken from Sinclair (1969); those for CaF₂ and CaF₂:Mn are from Attix (1970). Both references were derived from the data of J. H. Hubbell, as published in the review by Evans (1968).

^bCaF₂:Mn (TLD phosphor) is 49.5% Ca, 48.4% F, and 2.1% Mn by weight.

...16/-

APPENDIX E. Electron Mass Stopping Powers, Ranges, Radiation Yields, and Density Corrections^a

Hydrogen						
ENERGY	COLLISION	STOPPING POWER	TOTAL	CSDA	RADIATION	DENS. EFF.
MeV	cm ² /g	MeV cm ² /g	MeV cm ² /g	RANGE	YIELD	(DELTA)
				g/cm ²		
0.0100	3.125E+01	9.702E-04	5.122E+01	1.074E-04	1.029E-05	0.0
0.0125	4.271E+01	9.793E-04	4.271E+01	1.613E-04	1.282E-05	0.0
0.0150	3.622E+01	9.861E-04	3.622E+01	2.243E-04	1.430E-05	0.0
0.0175	3.247E+01	7.64E-04	3.247E+01	2.770E-04	1.584E-05	0.0
0.0200	2.939E+01	1.018E-03	2.939E+01	3.422E-04	1.744E-05	0.0
0.0250	2.118E+01	1.034E-03	2.118E+01	7.876E-04	2.528E-05	0.0
0.0300	1.870E+01	1.046E-03	1.870E+01	1.040E-03	3.003E-05	0.0
0.0400	1.687E+01	1.061E-03	1.687E+01	1.322E-03	3.371E-05	0.0
0.0500	1.542E+01	1.074E-03	1.542E+01	1.632E-03	3.733E-05	0.0
0.0550	1.424E+01	1.088E-03	1.424E+01	1.970E-03	4.090E-05	0.0
0.0600	1.327E+01	1.101E-03	1.327E+01	2.334E-03	4.435E-05	0.0
0.0650	1.255E+01	1.113E-03	1.255E+01	2.724E-03	4.761E-05	0.0
0.0700	1.144E+01	1.138E-03	1.144E+01	3.175E-03	5.075E-05	0.0
0.0800	1.015E+01	1.164E-03	1.015E+01	4.517E-03	5.479E-05	0.0
0.0900	9.367E+00	1.190E-03	9.367E+00	5.543E-03	5.866E-05	0.0
0.1000	8.737E+00	1.216E-03	8.737E+00	6.650E-03	6.237E-05	0.0
0.1250	7.590E+00	1.285E-03	7.590E+00	9.732E-03	7.050E-05	0.0
0.1500	6.819E+00	1.357E-03	6.819E+00	1.322E-02	7.618E-05	0.0
0.1750	6.266E+00	1.433E-03	6.266E+00	1.705E-02	8.075E-05	0.0
0.2000	5.851E+00	1.511E-03	5.851E+00	2.182E-02	8.467E-05	0.0
0.2500	5.275E+00	1.677E-03	5.275E+00	3.021E-02	1.070E-04	0.0
0.3000	4.898E+00	1.822E-03	4.898E+00	4.007E-02	1.271E-04	0.0
0.3500	4.635E+00	2.038E-03	4.635E+00	5.057E-02	1.471E-04	0.0
0.4000	4.465E+00	2.322E-03	4.465E+00	6.189E-02	1.672E-04	0.0
0.4500	4.302E+00	2.636E-03	4.302E+00	7.365E-02	1.874E-04	0.0
0.5000	4.193E+00	2.946E-03	4.193E+00	8.480E-02	2.076E-04	0.0
0.5500	4.109E+00	3.269E-03	4.109E+00	9.684E-02	2.278E-04	0.0
0.6000	4.042E+00	3.596E-03	4.042E+00	1.091E-01	2.480E-04	0.0
0.7000	3.945E+00	3.573E-03	3.945E+00	1.341E-01	2.682E-04	0.0
0.8000	3.883E+00	4.076E-03	3.883E+00	1.597E-01	2.884E-04	0.0
0.9000	3.842E+00	4.603E-03	3.842E+00	1.856E-01	3.086E-04	0.0
1.0000	3.816E+00	5.152E-03	3.816E+00	2.177E-01	3.288E-04	0.0
1.2500	3.787E+00	6.614E-03	3.787E+00	2.774E-01	3.490E-04	0.0
1.5000	3.788E+00	8.190E-03	3.788E+00	3.433E-01	3.692E-04	0.0
1.7500	3.802E+00	9.862E-03	3.802E+00	4.090E-01	3.894E-04	0.0
2.0000	3.823E+00	1.162E-02	3.823E+00	4.744E-01	4.096E-04	0.0
2.5000	3.873E+00	1.534E-02	3.873E+00	6.355E-01	4.298E-04	0.0
3.0000	3.924E+00	1.931E-02	3.924E+00	7.916E-01	4.499E-04	0.0
3.5000	3.975E+00	2.348E-02	3.975E+00	9.575E-01	4.699E-04	0.0
4.0000	4.020E+00	2.782E-02	4.020E+00	1.125E-01	4.899E-04	0.0
4.5000	4.061E+00	3.235E-02	4.061E+00	1.305E+00	5.099E-04	0.0
5.0000	4.102E+00	3.695E-02	4.102E+00	1.485E+00	5.299E-04	0.0
5.5000	4.150E+00	4.144E-02	4.150E+00	1.665E+00	5.499E-04	0.0
6.0000	4.175E+00	4.551E-02	4.175E+00	1.845E+00	5.699E-04	0.0
7.0000	4.239E+00	5.447E-02	4.239E+00	2.225E+00	5.899E-04	0.0
8.0000	4.295E+00	6.675E-02	4.295E+00	2.605E+00	6.099E-04	0.0
9.0000	4.345E+00	7.751E-02	4.345E+00	2.985E+00	6.299E-04	0.0
10.0000	4.391E+00	8.809E-02	4.391E+00	3.365E+00	6.499E-04	0.0
12.5000	4.488E+00	1.159E-01	4.488E+00	4.045E+00	6.699E-04	0.0
15.0000	4.569E+00	1.544E-01	4.569E+00	4.715E+00	6.899E-04	0.0
20.0000	4.688E+00	2.045E-01	4.688E+00	5.385E+00	7.099E-04	0.0
25.0000	4.792E+00	2.564E-01	4.792E+00	6.055E+00	7.299E-04	0.0
30.0000	4.881E+00	3.095E-01	4.881E+00	6.725E+00	7.499E-04	0.0
35.0000	4.951E+00	3.635E-01	4.951E+00	7.395E+00	7.699E-04	0.0
40.0000	5.010E+00	4.185E-01	5.010E+00	8.065E+00	7.899E-04	0.0
45.0000	5.053E+00	4.745E-01	5.053E+00	8.735E+00	8.099E-04	0.0
50.0000	5.091E+00	5.305E-01	5.091E+00	9.405E+00	8.299E-04	0.0
55.0000	5.120E+00	5.865E-01	5.120E+00	1.0075E+01	8.499E-04	0.0
60.0000	5.144E+00	6.425E-01	5.144E+00	1.0745E+01	8.699E-04	0.0
70.0000	5.183E+00	8.715E-01	5.183E+00	1.335E+01	8.899E-04	0.0
80.0000	5.213E+00	1.011E+00	5.213E+00	1.518E+01	9.099E-04	0.0
90.0000	5.238E+00	1.153E+00	5.238E+00	1.677E+01	9.299E-04	0.0

^aBerger and Seltzer, 1983. Reproduced with permission from M. J. Berger.

APPENDIX E. (Continued)

Silicon

ENERGY MeV	STOPPING POWER RADIATIVE		TOTAL MeV cm ² /g	CSDA RANGE g/cm ²	RADIATION YIELD	DEKS EFF. CORR. (DELTA)
	MeV cm ² /g	MeV cm ² /g				
0.0100	1.648E+01	6.559E-03	1.650E+01	3.539E-04	2.132E-04	3.539E-04
0.0125	1.398E+01	6.700E-03	1.398E+01	3.539E-04	2.583E-04	4.373E-04
0.0150	1.282E+01	6.781E-03	1.282E+01	3.539E-04	3.016E-04	4.373E-04
0.0175	1.088E+01	6.871E-03	1.088E+01	3.539E-04	3.332E-04	4.373E-04
0.0200	9.845E+00	6.948E-03	9.845E+00	3.539E-04	3.611E-04	4.373E-04
0.0250	8.345E+00	7.048E-03	8.345E+00	3.539E-04	4.133E-04	4.373E-04
0.0300	7.351E+00	7.148E-03	7.351E+00	3.539E-04	4.615E-04	4.373E-04
0.0350	6.506E+00	7.248E-03	6.506E+00	3.539E-04	5.058E-04	4.373E-04
0.0400	5.802E+00	7.348E-03	5.802E+00	3.539E-04	5.462E-04	4.373E-04
0.0450	5.200E+00	7.448E-03	5.200E+00	3.539E-04	5.827E-04	4.373E-04
0.0500	4.680E+00	7.548E-03	4.680E+00	3.539E-04	6.153E-04	4.373E-04
0.0550	4.230E+00	7.648E-03	4.230E+00	3.539E-04	6.440E-04	4.373E-04
0.0600	3.840E+00	7.748E-03	3.840E+00	3.539E-04	6.688E-04	4.373E-04
0.0650	3.500E+00	7.848E-03	3.500E+00	3.539E-04	6.898E-04	4.373E-04
0.0700	3.200E+00	7.948E-03	3.200E+00	3.539E-04	7.069E-04	4.373E-04
0.0750	2.940E+00	8.048E-03	2.940E+00	3.539E-04	7.201E-04	4.373E-04
0.0800	2.710E+00	8.148E-03	2.710E+00	3.539E-04	7.295E-04	4.373E-04
0.0850	2.510E+00	8.248E-03	2.510E+00	3.539E-04	7.351E-04	4.373E-04
0.0900	2.330E+00	8.348E-03	2.330E+00	3.539E-04	7.379E-04	4.373E-04
0.1000	1.970E+00	8.548E-03	1.970E+00	3.539E-04	7.483E-04	4.373E-04
0.1250	1.520E+00	8.948E-03	1.520E+00	3.539E-04	7.883E-04	4.373E-04
0.1500	1.180E+00	9.348E-03	1.180E+00	3.539E-04	8.283E-04	4.373E-04
0.1750	9.00E+00	9.748E-03	9.00E+00	3.539E-04	8.683E-04	4.373E-04
0.2000	6.80E+00	1.0148E-02	6.80E+00	3.539E-04	9.083E-04	4.373E-04
0.2500	4.60E+00	1.0548E-02	4.60E+00	3.539E-04	9.483E-04	4.373E-04
0.3000	3.10E+00	1.0948E-02	3.10E+00	3.539E-04	9.883E-04	4.373E-04
0.3500	2.20E+00	1.1348E-02	2.20E+00	3.539E-04	1.0283E-03	4.373E-04
0.4000	1.60E+00	1.1748E-02	1.60E+00	3.539E-04	1.0683E-03	4.373E-04
0.4500	1.20E+00	1.2148E-02	1.20E+00	3.539E-04	1.1083E-03	4.373E-04
0.5000	9.00E+00	1.2548E-02	9.00E+00	3.539E-04	1.1483E-03	4.373E-04
0.5500	6.80E+00	1.2948E-02	6.80E+00	3.539E-04	1.1883E-03	4.373E-04
0.6000	5.20E+00	1.3348E-02	5.20E+00	3.539E-04	1.2283E-03	4.373E-04
0.6500	4.00E+00	1.3748E-02	4.00E+00	3.539E-04	1.2683E-03	4.373E-04
0.7000	3.10E+00	1.4148E-02	3.10E+00	3.539E-04	1.3083E-03	4.373E-04
0.7500	2.40E+00	1.4548E-02	2.40E+00	3.539E-04	1.3483E-03	4.373E-04
0.8000	1.90E+00	1.4948E-02	1.90E+00	3.539E-04	1.3883E-03	4.373E-04
0.8500	1.50E+00	1.5348E-02	1.50E+00	3.539E-04	1.4283E-03	4.373E-04
0.9000	1.20E+00	1.5748E-02	1.20E+00	3.539E-04	1.4683E-03	4.373E-04
1.0000	8.00E+00	1.6148E-02	8.00E+00	3.539E-04	1.5083E-03	4.373E-04
1.2500	5.00E+00	1.6548E-02	5.00E+00	3.539E-04	1.5483E-03	4.373E-04
1.5000	3.50E+00	1.6948E-02	3.50E+00	3.539E-04	1.5883E-03	4.373E-04
1.7500	2.60E+00	1.7348E-02	2.60E+00	3.539E-04	1.6283E-03	4.373E-04
2.0000	2.00E+00	1.7748E-02	2.00E+00	3.539E-04	1.6683E-03	4.373E-04
2.5000	1.40E+00	1.8148E-02	1.40E+00	3.539E-04	1.7083E-03	4.373E-04
3.0000	1.00E+00	1.8548E-02	1.00E+00	3.539E-04	1.7483E-03	4.373E-04
3.5000	7.50E+00	1.8948E-02	7.50E+00	3.539E-04	1.7883E-03	4.373E-04
4.0000	5.80E+00	1.9348E-02	5.80E+00	3.539E-04	1.8283E-03	4.373E-04
4.5000	4.60E+00	1.9748E-02	4.60E+00	3.539E-04	1.8683E-03	4.373E-04
5.0000	3.70E+00	2.0148E-02	3.70E+00	3.539E-04	1.9083E-03	4.373E-04
5.5000	3.00E+00	2.0548E-02	3.00E+00	3.539E-04	1.9483E-03	4.373E-04
6.0000	2.50E+00	2.0948E-02	2.50E+00	3.539E-04	1.9883E-03	4.373E-04
6.5000	2.10E+00	2.1348E-02	2.10E+00	3.539E-04	2.0283E-03	4.373E-04
7.0000	1.80E+00	2.1748E-02	1.80E+00	3.539E-04	2.0683E-03	4.373E-04
7.5000	1.50E+00	2.2148E-02	1.50E+00	3.539E-04	2.1083E-03	4.373E-04
8.0000	1.30E+00	2.2548E-02	1.30E+00	3.539E-04	2.1483E-03	4.373E-04
8.5000	1.10E+00	2.2948E-02	1.10E+00	3.539E-04	2.1883E-03	4.373E-04
9.0000	1.00E+00	2.3348E-02	1.00E+00	3.539E-04	2.2283E-03	4.373E-04
10.0000	8.00E+00	2.3748E-02	8.00E+00	3.539E-04	2.2683E-03	4.373E-04
12.5000	5.00E+00	2.4148E-02	5.00E+00	3.539E-04	2.3083E-03	4.373E-04
15.0000	3.50E+00	2.4548E-02	3.50E+00	3.539E-04	2.3483E-03	4.373E-04
17.5000	2.60E+00	2.4948E-02	2.60E+00	3.539E-04	2.3883E-03	4.373E-04
20.0000	2.00E+00	2.5348E-02	2.00E+00	3.539E-04	2.4283E-03	4.373E-04
25.0000	1.40E+00	2.5748E-02	1.40E+00	3.539E-04	2.4683E-03	4.373E-04
30.0000	1.00E+00	2.6148E-02	1.00E+00	3.539E-04	2.5083E-03	4.373E-04
35.0000	7.50E+00	2.6548E-02	7.50E+00	3.539E-04	2.5483E-03	4.373E-04
40.0000	5.80E+00	2.6948E-02	5.80E+00	3.539E-04	2.5883E-03	4.373E-04
45.0000	4.60E+00	2.7348E-02	4.60E+00	3.539E-04	2.6283E-03	4.373E-04
50.0000	3.70E+00	2.7748E-02	3.70E+00	3.539E-04	2.6683E-03	4.373E-04
55.0000	3.00E+00	2.8148E-02	3.00E+00	3.539E-04	2.7083E-03	4.373E-04
60.0000	2.50E+00	2.8548E-02	2.50E+00	3.539E-04	2.7483E-03	4.373E-04
65.0000	2.10E+00	2.8948E-02	2.10E+00	3.539E-04	2.7883E-03	4.373E-04
70.0000	1.80E+00	2.9348E-02	1.80E+00	3.539E-04	2.8283E-03	4.373E-04
75.0000	1.50E+00	2.9748E-02	1.50E+00	3.539E-04	2.8683E-03	4.373E-04
80.0000	1.30E+00	3.0148E-02	1.30E+00	3.539E-04	2.9083E-03	4.373E-04
85.0000	1.10E+00	3.0548E-02	1.10E+00	3.539E-04	2.9483E-03	4.373E-04
90.0000	1.00E+00	3.0948E-02	1.00E+00	3.539E-04	2.9883E-03	4.373E-04

Aluminum

APPENDIX E. (Continued)

ENERGY MeV	STOPPING POWER RADIATIVE		TOTAL MeV cm ² /g	CSDA RANGE g/cm ²	RADIATION YIELD	DEKS EFF. CORR. (DELTA)
	MeV cm ² /g	MeV cm ² /g				
0.0100	1.648E+01	6.559E-03	1.650E+01	3.539E-04	2.132E-04	3.539E-04
0.0125	1.398E+01	6.700E-03	1.398E+01	3.539E-04	2.583E-04	4.373E-04
0.0150	1.282E+01	6.781E-03	1.282E+01	3.539E-04	3.016E-04	4.373E-04
0.0175	1.088E+01	6.871E-03	1.088E+01	3.539E-04	3.332E-04	4.373E-04
0.0200	9.845E+00	6.948E-03	9.845E+00	3.539E-04	3.611E-04	4.373E-04
0.0250	8.345E+00	7.048E-03	8.345E+00	3.539E-04	4.133E-04	4.373E-04
0.0300	7.351E+00	7.148E-03	7.351E+00	3.539E-04	4.615E-04	4.373E-04
0.0350	6.506E+00	7.248E-03	6.506E+00	3.539E-04	5.058E-04	4.373E-04
0.0400	5.802E+00	7.348E-03	5.802E+00	3.539E-04	5.462E-04	4.373E-04
0.0450	5.200E+00	7.448E-03	5.200E+00	3.539E-04	5.827E-04	4.373E-04
0.0500	4.680E+00	7.548E-03	4.680E+00	3.539E-04	6.153E-04	4.373E-04
0.0550	4.230E+00	7.648E-03	4.230E+00	3.539E-04	6.440E-04	4.373E-04
0.0600	3.840E+00	7.748E-03	3.840E+00	3.539E-04	6.688E-04	4.373E-04
0.0650	3.500E+00	7.848E-03	3.500E+00	3.539E-04	6.898E-04	4.373E-04
0.0700	3.200E+00	7.948E-03	3.200E+00	3.539E-04	7.069E-04	4.373E-04
0.0750	2.940E+00	8.048E-03	2.940E+00	3.539E-04	7.201E-04	4.373E-04
0.0800	2.710E+00	8.148E-03	2.710E+00	3.539E-04	7.295E-04	4.373E-04
0.0850	2.510E+00	8.248E-03	2.510E+00	3.539E-04	7.351E-04	4.373E-04
0.0900	2.330E+00	8.348E-03	2.330E+00	3.539E-04	7.379E-04	4.373E-04
0.1000	1.970E+00	8.548E-03	1.970E+00	3.539E-04	7.483E-04	4.373E-04
0.1250	1.520E+00	8.948E-03	1.520E+00	3.539E-04	7.883E-04	4.373E-04
0.1500	1.180E+00	9.348E-03	1.180E+00	3.539E-04	8.283E-04	4.373E-04
0.1750	9.00E+00	9.748E-03	9.00E+00	3.539E-04	8.683E-04	4.373E-04
0.2000	6.80E+00	1.0148E-02	6.80E+00	3.539E-04	9.083E-04	4.373E-04
0.2500	4.60E+00	1.0548E-02	4.60E+00	3.539E-04	9.483E-04	4.373E-04
0.3000	3.10E+00	1.0948E-02	3.10E+00	3.539E-04	9.883E-04	4.373E-04
0.3500	2.20E+00	1.1348E-02	2.20E+00	3.539E-04	1.0283E-03	4.373E-04
0.4000	1.60E+00	1.1748E-02	1.60E+00	3.539E-04	1.0683E-03	4.373E-04
0.4500	1.20E+00	1.2148E-02	1.20E+00	3.539E-04	1.1083E-03	4.373E-04
0.5000	9.00E+00	1.2548E-02	9.00E+00	3.539E-04	1.1483E-03	4.373E-04
0.5500	6.80E+00	1.2948E-02	6.80E+00	3.539E-04	1.1883E-03	4.373E-04
0.6000	5.20E+00	1.3348E-02	5.20E+00	3.539E-04	1.2283E-03	4.373E-04
0.6500	4.00E+00	1.3748E-02	4.00E+00	3.539E-04	1.2683E-03	4.373E-04
0.7000	3.10E+00	1.4148E-02	3.10E+00	3.539E-04	1.3083E-03	4.373E-04
0.7500	2.40E+00	1.4548E-02	2.40E+00	3.539E-04	1.3483E-03	4.373E-04
0.8000	1.90E+00	1.4948E-02	1.90E+00	3.539E-04	1.3883E-03	4.373E-04
0.8500	1.50E+00	1.5348E-02	1.50E+00	3.539E-04	1.4283E-03	4.373E-04
0.9000	1.20E+00	1.5748E-02	1.20E+00	3.539E-04	1.4683E-03	4.373E-04
1.0000	8.00E+00	1.6148E-02	8.00E+00	3.539E-04	1.5083E-03	4.373E-04
1.2500	5.00E+00	1.6548E-02	5.00E+00	3.539E-04	1.5483E-03	4.373E-04
1.5000	3.50E+00	1.6948E-02	3.50E+00	3.539E-04	1.5883E-03	4.373E-04

APPENDIX E. (Continued)

Copper

ENERGY MeV	COLLISION RADIATIVE		STOPPING POWER RADIATIVE		TOTAL MeV cm ² /g	CSDA RANGE g/cm ²	RADIATION YIELD	DENS. EFF. CORR. (DELTA)
	MeV cm ² /g	MeV cm ² /g	MeV cm ² /g	MeV cm ² /g				
0.0100	1.318E+01	1.213E-02	1.318E+01	4.601E-04	1.318E+01	4.601E-04	4.701E-04	1.244E-03
0.0125	1.127E+01	1.277E-02	1.127E+01	6.658E-04	1.127E+01	6.658E-04	5.814E-04	1.385E-03
0.0150	9.304E+00	1.327E-02	9.304E+00	9.028E-04	9.304E+00	9.028E-04	6.964E-04	1.386E-03
0.0175	8.874E+00	1.366E-02	8.874E+00	1.170E-03	8.874E+00	1.170E-03	7.972E-04	2.304E-03
0.0200	8.085E+00	1.398E-02	8.085E+00	1.492E-03	8.085E+00	1.492E-03	9.041E-04	2.663E-03
0.0250	6.040E+00	1.488E-02	6.040E+00	2.912E-03	6.040E+00	2.912E-03	1.307E-03	4.334E-03
0.0300	5.416E+00	1.518E-02	5.416E+00	3.768E-03	5.416E+00	3.768E-03	1.491E-03	5.247E-03
0.0400	4.931E+00	1.563E-02	4.931E+00	4.947E+00	4.931E+00	4.947E-03	1.674E-03	6.320E-03
0.0500	4.544E+00	1.583E-02	4.544E+00	5.808E+00	4.544E+00	5.808E-03	1.852E-03	7.259E-03
0.0600	4.226E+00	1.593E-02	4.226E+00	6.946E+00	4.226E+00	6.946E-03	2.025E-03	8.163E-03
0.0800	3.714E+00	1.600E-02	3.714E+00	8.144E-03	3.714E+00	8.144E-03	2.194E-03	9.342E-03
0.1000	3.375E+00	1.615E-02	3.375E+00	9.459E-03	3.375E+00	9.459E-03	2.358E-03	1.080E-02
0.1250	3.098E+00	1.641E-02	3.098E+00	1.227E-02	3.098E+00	1.227E-02	2.674E-03	1.354E-02
0.1500	2.877E+00	1.665E-02	2.877E+00	1.555E-02	2.877E+00	1.555E-02	2.977E-03	1.644E-02
0.2000	2.877E+00	1.688E-02	2.877E+00	1.688E-02	2.877E+00	1.688E-02	3.247E-03	2.013E-02
0.3000	2.698E+00	1.710E-02	2.698E+00	2.225E-02	2.698E+00	2.225E-02	3.547E-03	2.404E-02
0.4000	2.370E+00	1.816E-02	2.370E+00	3.211E-02	2.370E+00	3.211E-02	4.208E-03	3.883E-02
0.5000	1.946E+00	1.870E-02	1.946E+00	4.314E-02	1.946E+00	4.314E-02	4.822E-03	5.053E-02
0.7500	1.984E+00	1.870E-02	1.984E+00	5.517E-02	1.984E+00	5.517E-02	5.401E-03	6.758E-02
0.2000	1.811E+00	1.926E-02	1.811E+00	6.897E-02	1.811E+00	6.897E-02	5.950E-03	8.393E-02
0.2500	1.691E+00	2.045E-02	1.691E+00	8.695E-02	1.691E+00	8.695E-02	6.381E-03	9.236E-02
0.3000	1.591E+00	2.172E-02	1.591E+00	1.101E-01	1.591E+00	1.101E-01	6.745E-03	1.036E-01
0.3500	1.501E+00	2.307E-02	1.501E+00	1.384E-01	1.501E+00	1.384E-01	7.045E-03	1.158E-01
0.4000	1.444E+00	2.450E-02	1.444E+00	1.818E-01	1.444E+00	1.818E-01	7.302E-03	1.302E-01
0.5000	1.402E+00	2.595E-02	1.402E+00	2.297E-01	1.402E+00	2.297E-01	7.525E-03	1.455E-01
0.7500	1.348E+00	2.747E-02	1.348E+00	3.078E-01	1.348E+00	3.078E-01	7.716E-03	1.626E-01
1.0000	1.281E+00	2.893E-02	1.281E+00	4.039E-01	1.281E+00	4.039E-01	7.876E-03	1.817E-01
1.5000	1.207E+00	3.053E-02	1.207E+00	5.264E-01	1.207E+00	5.264E-01	7.999E-03	2.029E-01
2.0000	1.133E+00	3.223E-02	1.133E+00	6.867E-01	1.133E+00	6.867E-01	8.083E-03	2.262E-01
3.0000	1.059E+00	3.403E-02	1.059E+00	8.952E-01	1.059E+00	8.952E-01	8.131E-03	2.516E-01
4.0000	1.000E+00	3.593E-02	1.000E+00	1.163E+00	1.000E+00	1.163E+00	8.155E-03	2.789E-01
5.0000	9.520E+00	3.793E-02	9.520E+00	1.500E+00	9.520E+00	1.500E+00	8.155E-03	3.081E-01
6.0000	9.136E+00	3.993E-02	9.136E+00	1.900E+00	9.136E+00	1.900E+00	8.155E-03	3.391E-01
7.0000	8.800E+00	4.193E-02	8.800E+00	2.370E+00	8.800E+00	2.370E+00	8.155E-03	3.719E-01
8.0000	8.500E+00	4.393E-02	8.500E+00	2.920E+00	8.500E+00	2.920E+00	8.155E-03	4.065E-01
9.0000	8.230E+00	4.593E-02	8.230E+00	3.550E+00	8.230E+00	3.550E+00	8.155E-03	4.429E-01
10.0000	8.000E+00	4.793E-02	8.000E+00	4.270E+00	8.000E+00	4.270E+00	8.155E-03	4.811E-01
12.5000	7.500E+00	5.193E-02	7.500E+00	5.680E+00	7.500E+00	5.680E+00	8.155E-03	5.619E-01
15.0000	7.000E+00	5.593E-02	7.000E+00	7.370E+00	7.000E+00	7.370E+00	8.155E-03	6.465E-01
17.5000	6.500E+00	5.993E-02	6.500E+00	9.450E+00	6.500E+00	9.450E+00	8.155E-03	7.449E-01
20.0000	6.000E+00	6.393E-02	6.000E+00	1.200E+01	6.000E+00	1.200E+01	8.155E-03	8.581E-01
25.0000	5.000E+00	7.193E-02	5.000E+00	1.600E+01	5.000E+00	1.600E+01	8.155E-03	1.100E+01
30.0000	4.000E+00	7.993E-02	4.000E+00	2.100E+01	4.000E+00	2.100E+01	8.155E-03	1.380E+01
35.0000	3.500E+00	8.793E-02	3.500E+00	2.700E+01	3.500E+00	2.700E+01	8.155E-03	1.700E+01
40.0000	3.000E+00	9.593E-02	3.000E+00	3.400E+01	3.000E+00	3.400E+01	8.155E-03	2.070E+01
45.0000	2.500E+00	1.039E-01	2.500E+00	4.200E+01	2.500E+00	4.200E+01	8.155E-03	2.500E+01
50.0000	2.000E+00	1.119E-01	2.000E+00	5.100E+01	2.000E+00	5.100E+01	8.155E-03	2.990E+01
55.0000	1.611E+00	1.199E-01	1.611E+00	6.100E+01	1.611E+00	6.100E+01	8.155E-03	3.540E+01
60.0000	1.311E+00	1.279E-01	1.311E+00	7.200E+01	1.311E+00	7.200E+01	8.155E-03	4.160E+01
70.0000	1.032E+00	1.439E-01	1.032E+00	9.400E+01	1.032E+00	9.400E+01	8.155E-03	5.270E+01
80.0000	8.844E+00	1.599E-01	8.844E+00	1.200E+02	8.844E+00	1.200E+02	8.155E-03	6.530E+01
90.0000	7.536E+00	1.759E-01	7.536E+00	1.500E+02	7.536E+00	1.500E+02	8.155E-03	7.950E+01

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APPENDIX E. (Continued)

ENERGY MeV	COLLISION RADIATIVE		STOPPING POWER RADIATIVE		TOTAL MeV cm ² /g	CSDA RANGE g/cm ²	RADIATION YIELD	DENS. EFF. CORR. (DELTA)
	MeV cm ² /g	MeV cm ² /g	MeV cm ² /g	MeV cm ² /g				
0.0100	1.075E+01	1.645E-02	1.075E+01	5.861E-04	1.075E+01	5.861E-04	7.574E-04	6.464E-04
0.0125	9.263E+00	1.765E-02	9.263E+00	8.211E-04	9.263E+00	8.211E-04	6.371E-04	6.371E-04
0.0150	8.186E+00	1.885E-02	8.186E+00	1.124E-03	8.186E+00	1.124E-03	5.140E-04	1.140E-03
0.0175	7.366E+00	1.951E-02	7.366E+00	1.446E-03	7.366E+00	1.446E-03	4.329E-04	1.329E-03
0.0200	6.718E+00	2.021E-02	6.718E+00	1.801E-03	6.718E+00	1.801E-03	3.515E-04	1.515E-03
0.0250	5.758E+00	2.135E-02	5.758E+00	2.605E-03	5.758E+00	2.605E-03	2.882E-04	1.812E-03
0.0300	5.078E+00	2.229E-02	5.078E+00	3.528E-03	5.078E+00	3.528E-03	2.339E-04	2.158E-03
0.0350	4.567E+00	2.299E-02	4.567E+00	4.584E-03	4.567E+00	4.584E-03	2.389E-04	2.827E-03
0.0400	4.169E+00	2.362E-02	4.169E+00	5.705E-03	4.169E+00	5.705E-03	2.931E-04	3.315E-03
0.0500	3.502E+00	2.422E-02	3.502E+00	6.947E-03	3.502E+00	6.947E-03	3.266E-04	3.826E-03
0.0600	3.087E+00	2.472E-02	3.087E+00	8.285E-03	3.087E+00	8.285E-03	3.955E-04	4.355E-03
0.0800	2.518E+00	2.565E-02	2.518E+00	9.714E-03	2.518E+00	9.714E-03	3.917E-04	4.904E-03
0.1000	2.180E+00	2.645E-02	2.180E+00	1.123E-02	2.180E+00	1.123E-02	4.233E-04	5.473E-03
0.1250	1.880E+00	2.695E-02	1.880E+00	1.291E-02	1.880E+00	1.291E-02	4.449E-04	6.067E-03
0.1500	1.645E+00	2.735E-02	1.645E+00	1.480E-02	1.645E+00	1.480E-02	4.649E-04	6.677E-03
0.2000	1.380E+00	2.775E-02	1.380E+00	1.810E-02	1.380E+00	1.810E-02	5.023E-04	7.352E-03
0.3000	1.152E+00	2.835E-02	1.152E+00	2.472E-02	1.152E+00	2.472E-02	5.423E-04	8.023E-03
0.4000	1.000E+00	2.895E-02	1.000E+00	3.338E-02	1.000E+00	3.338E-02	5.884E-04	8.684E-03
0.5000	9.250E+00	2.955E-02	9.250E+00	4.412E-02	9.250E+00	4.412E-02	6.394E-04	9.314E-03
0.7500	8.150E+00	3.015E-02	8.150E+00	5.701E-02	8.150E+00	5.701E-02	7.125E-04	1.075E-02
1.0000	7.250E+00	3.075E-02	7.250E+00	7.174E-02	7.250E+00	7.174E-02	7.725E-04	1.235E-02
1.5000	6.150E+00	3.135E-02	6.150E+00	9.848E-02	6.150E+00	9.848E-02	8.325E-04	1.405E-02
2.0000	5.250E+00	3.195E-02	5.250E+00	1.280E-01	5.250E+00	1.280E-01	8.825E-04	1.585E-02
3.0000	4.150E+00	3.255E-02	4.150E+00	1.704E-01	4.150E+00	1.704E-01	9.325E-04	1.775E-02
4.0000	3.250E+00	3.315E-02	3.250E+00	2.264E-01	3.250E+00	2.264E-01	9.825E-04	1.975E-02
5.0000	2.550E+00	3.375E-02	2.550E+00	2.968E-01	2.550E+00	2.968E-01	1.0325E-03	2.185E-02
6.0000	2.050E+00	3.435E-02	2.050E+00	3.816E-01	2.050E+00	3.816E-01	1.0825E-03	2.405E-02
7.0000	1.650E+00	3.495E-02	1.650E+00	4.808E-01	1.650E+00	4.808E-01	1.1325E-03	2.635E-02
8.0000	1.350E+00	3.555E-02	1.350E+00	5.956E-01	1.350E+00	5.956E-01	1.1825E-03	2.875E-02
9.0000	1.150E+00	3.615E-02	1.150E+00	7.264E-01	1.150E+00	7.264E-01	1.2325E-03	3.125E-02
10.0000	1.000E+00	3.675E-02	1.000E+00	8.732E-01	1.000E+00	8.732E-01	1.2825E-03	3.385E-02
12.5000	8.000E+00	3.735E-02	8.000E+00	1.146E+00	8.000E+00	1.146E+00	1.3325E-03	3.645E-02
15.0000	7.000E+00	3.795E-02	7.000E+00	1.452E+00	7.000E+00	1.452E+00	1.3825E-03	3.905E-02
17.5000	6.000E+00	3.855E-02	6.000E+00	1.790E+00	6.000E+00	1.790E+00	1.4325E-03	4.165E-02
20.0000	5.000E+00	3.915E-02	5.000E+00	2.350E+00	5.000E+00	2.350E+00	1.4825E-03	4.425E-02
25.0000	4.000E+00	3.975E-02	4.000E+00	3.140E+00	4.000E+00	3.140E+00	1.5325E-03	4.685E-02
30.0000	3.000E+00	4.035E-02	3.000E+00	4.160E+00	3.000E+00	4.160E+00	1.5825E-03	4.945E-02
35.0000	2.500E+00	4.095E-02	2.500E+00	5.420E+00	2.500E+00	5.420E+00	1.6325E-03	5.205E-02
40.0000	2.000E+00	4.155E-02	2.000E+00					