RADIATION HYGIENE HANDBOOK

A PRACTICAL REFERENCE COVERING THE INDUSTRIAL, MEDICAL, AND RESEARCH USES OF RADIATION AND ATOMIC ENERGY WITH SPECIAL APPLICATIONS TO THE FIELDS OF HEALTH PHYSICS, INDUSTRIAL HYGIENE, AND SANITARY ENGINEERING

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FOREWORD

The scope and complexity of radiation hygiene make it a fascinating field of study for those who enjoy the challenge of scientific variety.

Here is a subject that begins with the properties of the fundamental particles and the way in which they interact with matter—especially the matter of which living things are composed. Although these interactions take place at the lowest biochemical level, they may express themselves so as to involve the entire organism and, in the case of effects on the hereditary mechanisms, the entire race.

It is in the study of the dispersion of radioactive substances in the environment that one finds the greatest degree of interplay among the many branches of science. Meteorology, soil chemistry, the hydrologic sciences, and mineral metabolism are some of the subjects which are involved to a major degree in evaluating the significance of radioactive contamination.

The ultimate objective of the radiation hygienist is to recommend effective and yet economical methods of controlling radiation hazards. This frequently requires intimate knowledge of the procedures of laboratories and industrial processes. The job of the radiation hygienist does not stop with identification of a potential hazard: it is important that he assist as well in the solution of the problem.

Radiation hygienists today are for the most part specialists of one kind or another who have acquired more general knowledge through their working relationships with specialists from other fields. Logically, the first of the workers in the field of radiation protection were physicists, many of whom were concerned originally with dosimetric aspects of radiation exposure. In recent years the ranks of this new profession have attracted chemists, geologists, engineers, meteorologists, and biologists.

The interdisciplinary characteristic of the field creates problems of definition and purpose which must soon be solved if the needs of the expanding nuclear industry are to be met. Who is a radiation hygienist (or, for that matter, what is a health physicist)? What should he know, what should he do, where do his responsibilities begin, and where do they end? As our second and third generations of scientists and engineers enter this expanding field, our definitions must be improved, our standards for pro-

fessional qualification must be established, and our universities must adapt their curricula for the new requirements that the atomic age imposes.

The "Radiation Hygiene Handbook" will serve in an important way to assist science and industry to find the basic information with which radiation protection problems can be solved. For the first time, a compendium of information is available to permit the scientist and engineer to probe the many ramifications of health protection in the peaceful applications of atomic energy.

Merril Eisenbud

PREFACE

This is a new handbook to fill a new need. With the rapidly increasing use of radiation as a tool in industry, medicine, and research and the frequent appearance of radiation as an objectionable by-product in such fields as atomic energy for power and for transportation, the need for information and data to help protect workers and the public from its harmful effects is pressing.

This, the first comprehensive handbook in the field we chose to call "radiation hygiene," has been dependent upon the contributions, advice, and inspiration of many of the American leaders in this relatively new branch of science. The list of contributors, their areas of specialization, and their affiliations give some indication of the broadness of the subject.

Many different disciplines and many different philosophies are represented in this new field. On the one hand are the ultraconservatives, who believe that because of the many unknowns (particularly with regard to genetics) radioactive contamination and radiation exposures should be kept to the absolute minimum, regardless of cost. At the other extreme are those who prefer to wait for evidence of damage before instituting corrective measures.

In offering guidance to the various contributors, the editor has attempted to follow a reasonably "middle-of-the-road" philosophy as exemplified by many of the leaders in this field with which the editor has had the good fortune to be associated for many years: Shields Warren, John Bugher, G. Failla, Charles L. Dunham, Carl B. Braestrup, S. Allan Lough, William B. Harris, John H. Harley, Norton Nelson, and many others.

If any particular point of view is expressed in this handbook, it was perhaps influenced most by Merril Eisenbud, through whose leadership the AEC Health and Safety Laboratory has to a great extent set the pace in this rapidly expanding field of endeavor. To him, in particular, this book is dedicated.

Many of my former staff in the Radiation Branch of the Health and Safety Laboratory have been most generous in their advice, encouragement, and assistance, particularly Leonard R. Solon, James E. McLaughlin, Yvette Rosenberg, Pauline Castellani, and Josephine Lemma. Last, but by no means least, this formidable task could not have been completed without the infinite and loving patience of my wife Elizabeth and our family through these trying three years.

Hanson Blatz

CONTENTS

Section 1

REFERENCE DATA

By

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Acknowledgments. Some of the material in this section is from the "Radiological Health Handbook" of the U.S. Department of Health, Education and Welfare. Dr. Kinsman, as editor of the "Radiological Health Handbook," wishes to acknowledge the assistance of his many associates at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

Tables 1-15, 1-16, and 1-17 are based, in part, on data from the "Code of Practice for the Protection of Persons Exposed to Ionizing Radiations," British Radioactive Substances Standing Advisory Committee, H.M. Stationery Office, London, England (1957).

Tables 1-18, 1-19, and 1-20 are from the recommendations of the International Commission on Radiological Protection.

REFERENCE DATA

Hanson Blatz and Simon Kinsman

Table 1-1. Alphabetical Index of Elements and Their Atomic Numbers (*Z*)

Element	Symbol	*Z*	Element	Symbol	*Z*
Actinium	Ac	89	Molybdenum	Mo	42
Aluminum	Al	13	Neodymium	Nd	60
Americium	Am	95	Neon	Ne	10
Antimony	Sb	51	Neptunium	Np	93
Argon	A	18	Nickel	Ni	28
Arsenic	As	33	Niobium *	Nb	41
Astatine	At	85	Nitrogen	N	7
Barium	Ba	56	Osmium	Os	76
Berkelium	Bk	97	Oxygen	O	8
Beryllium	Be	4	Palladium	Pd	46
Bismuth	Bi	83	Phosphorus	P	15
Boron	B	5	Platinum	Pt	78
Bromine	Br	35	Plutonium	Pu	94
Cadmium	Cd	48	Polonium	Po	84
Calcium	Ca	20	Potassium	K	19
Californium	Cf	98	Praseodymium	Pr	59
Carbon	C	6	Promethium	Pm	61
Cerium	Ce	58	Protoactinium	Pa	91
Cesium	Cs	55	Radium	Ra	88
Chlorine	Cl	17	Radon †	Rn	86
Chromium	Cr	24	Rhenium	Re	75
Cobalt	Co	27	Rhodium	Rh	45
Copper	Cu	29	Rubidium	Rb	37
Curium	Cm	96	Ruthenium	Ru	44
Dysprosium	Dy	66	Samarium	Sm	62
Erbium	Er	68	Scandium	Sc	21
Europium	Eu	63	Selenium	Se	34
Fluorine	F	9	Silicon	Si	14
Francium	Fr	87	Silver	Ag	47
Gadolinium	Gd	64	Sodium	Na	11
Gallium	Ga	31	Strontium	Sr	38
Germanium	Ge	32	Sulfur	S	16
Gold	Au	79	Tantalum	Ta	73
Hafnium	Hf	72	Technetium	Tc	43
Helium	He	2	Tellurium	Te	52
Holmium	Ho	67	Terbium	Tb	65
Hydrogen	H	1	Thallium	Tl	81
Indium	In	49	Thorium	Th	90
Iodine	I	53	Thulium	Tm	69
Iridium	Ir	77	Tin	Sn	50
Iron	Fe	26	Titanium	Ti	22
Krypton	Kr	36	Uranium	U	92
Lanthanum	La	57	Vanadium	V	23
Lead	Pb	82	Wolfram ‡	W	74
Lithium	Li	3	Xenon	Xe	54
Lutecium	Lu	71	Ytterbium	Yb	70
Magnesium	Mg	12	Yttrium	Y	39
Manganese	Mn	25	Zinc	Zn	30
Mercury	Hg	80	Zirconium	Zr	40

* Formerly columbium (Cb). † Also called radium emanation. ‡ Also called tungsten.

Table 1-2. Half-lives of Common Radioactive Elements

Element	Half-life	Element	Half-life
Th-232	1.39×10^{10} y	Y-91	58 d
U-238	4.49×10^{9} y	Sr-89	53 d
U-235	7.13×10^{8} y	Fe-59	45 d
Cl-36	3.1×10^{5} y	Cr-51	27 d
U-233	1.62×10^{5} y	Th-234	24.1 d
Ni-59	8×10^{4} y	Rb-86	18.6 d
Pu-239	2.436×10^{4} y	P-32	14.5 d
C-14	5,600 y	Ba-140	12.8 d
Ra-226	1,622 y	I-131	8.05 d
Cs-137	30 y	Au-199	3.15 d
Sr-90	28 y	Au-198	2.7 d
H-3	12.26 y	Mo-99	67 h
Co-60	5.27 y	Y-90	64 h
Tl-204	4.1 y	La-140	40 h
Fe-55	2.9 y	Br-82	35.87 h
Pm-147	2.6 y	As-76	26.8 h
Cs-134	2.3 y	Na-24	15.0 h
Ru-106	1.0 y	Ga-72	14.1 h
Ce-144	285 d	Cu-64	12.8 h
Zn-65	245 d	K-42	12.5 h
Ca-45	160 d	Mn-56	2.576 h
Po-210	138.4 d	A-41	109 m
Ta-182	112 d	Pr-144	17 m
S-35	87 d	N-16	7.4 s
W-185	74 d	Po-212	3×10^{-7} s

Table 1-3. Fundamental Constants

Name		*Value*
Avogadro's number	N_0	$= 6.025 \times 10^{23}$ molecules/g mole
Base of natural logarithms	e	$= 2.7183\ldots$
Curie	c	$= 3.7 \times 10^{10}$ disintegrations/sec
Electron charge	e	$= 4.8 \times 10^{-10}$ statcoulomb
		$= 1.6 \times 10^{-19}$ coulomb
Energy equivalent of electron mass	mc^2	$= 0.51$ Mev
Faraday's constant	F	$= 96{,}514$ coulombs/g equivalent (physical scale)
Frequency associated with 1 ev	ν_0	$= 2.4186 \times 10^{14}$ sec^{-1}
Gravitational acceleration	g	$= 980.665$ cm/sec^2
Mass, alpha particle	m_α	$= 6.64 \times 10^{-24}$ g $= 4.002777$ mu
Mass, electron	m_e	$= 9.1066 \times 10^{-28}$ g $= 0.000548$ mu
Mass, H-atom	m_H	$= 1.67339 \times 10^{-24}$ g $= 1.008142$ mu
Mass, neutron	m_n	$= 1.6751 \times 10^{-24}$ g $= 1.008982$ mu
Mass, proton	m_p	$= 1.67248 \times 10^{-24}$ g $= 1.007594$ mu
Mass unit	mu	$= 1.66035 \times 10^{-24}$ g $= 1.0000$ mu
Microcurie	μc	$= 10^{-6}$ curie $= 3.7 \times 10^4$ disintegrations/sec
Micromicrocurie	$\mu\mu$c	$= 10^{-12}$ curie $= 3.7 \times 10^{-2}$ disintegration/sec
Millicurie	mc	$= 10^{-3}$ curie $= 3.7 \times 10^7$ disintegrations/sec
Planck's constant	h	$= 6.624 \times 10^{-27}$ erg-sec
Roentgen	r	$= 1$ esu/0.001293 g of air
Rutherford	rd	$= 10^6$ disintegrations/sec
Universal gas constant	R	$= 0.08206$ liter-atm/g-mole/°K
Velocity of light	c	$= 2.99776 \times 10^{10}$ cm/sec
Wavelength associated with 1 ev	λ_0	$= 12394.8$ A

Table 1-4. Signs and Symbols of Particular Interest in Radiation and Radioactivity

A or Å	angstrom (10^{-10} m)
A	activity (radioactivity)
A_0	activity (radioactivity), original
A_t	activity (radioactivity), at time t
b	build-up factor
c	curie
D	deuterium
d	deuteron
e	electron
I	radiation intensity
I_0	radiation intensity, initial
I_x	radiation intensity, transmitted
LD-50	median lethal dose
n	neutron
N	number of counts
N_0	number of counts, original
N_t	number of counts, at time t
h	Planck's constant
p	proton
r	roentgen
t	triton
α	alpha particle
β	beta particle
γ	gamma ray
λ	wavelength or decay constant
$\bar{\lambda}$	mean free path
u	linear absorption coefficient
σ	area (barn–cross section)

Table 1-5. Commonly Used Units

Units of radioactivity:		
$\mu\mu$c	**micromicrocurie**	10^{-12} curie
μc	**microcurie**	10^{-6} curie
c	curie	
kc	kilocurie	10^{3} curies
Mc	megacurie	10^{6} curies
Units of radiation:		
μr	microroentgen	10^{-6} roentgen
mr	milliroentgen	10^{-3} roentgen
r	roentgen	

The prefixes milli (m) and micro (μ) are also commonly used with the units rad, rep (obsolescent), and rem.

Units of energy (of radiation):		
ev	electron volt	
kev	kiloelectron volt	10^{3} electron volts
Mev	million electron volts	10^{6} electron volts
Bev	billion electron volts	10^{9} electron volts

Table 1-6. Logarithm Tables (Four-place) *

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396

* From Knowlton, A. E. (ed.), "Standard Handbook for Electrical Engineers," 9th ed., McGraw-Hill, 1957.

Table 1-6. Logarithm Tables (Four-place) *(Continued)*

N	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996

Table 1-7. Natural Trigonometric Functions *

Deg	°0.0	°0.1	°0.2	°0.3	°0.4	°0.5	°0.6	°0.7	°0.8	°0.9	
0	0.0000	0.0017	0.0035	0.0052	0.0070	0.0087	0.0105	0.0122	0.0140	0.0157	89
1	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332	88
2	0.0349	0.0366	0.0384	0.0401	0.0419	0.0436	0.0454	0.0471	0.0488	0.0506	87
3	0.0523	0.0541	0.0558	0.0576	0.0593	0.0610	0.0628	0.0645	0.0663	0.0680	86
4	0.0698	0.0715	0.0732	0.0750	0.0767	0.0785	0.0802	0.0819	0.0837	0.0854	85
5	0.0872	0.0889	0.0906	0.0924	0.0941	0.0958	0.0976	0.0993	0.1011	0.1028	84
6	0.1045	0.1063	0.1080	0.1097	0.1115	0.1132	0.1149	0.1167	0.1184	0.1201	83
7	0.1219	0.1236	0.1253	0.1271	0.1288	0.1305	0.1323	0.1340	0.1357	0.1374	82
8	0.1392	0.1409	0.1426	0.1444	0.1461	0.1478	0.1495	0.1513	0.1530	0.1547	81
9	0.1564	0.1582	0.1599	0.1616	0.1633	0.1650	0.1668	0.1685	0.1702	0.1719	80
10	0.1736	0.1754	0.1771	0.1788	0.1805	0.1822	0.1840	0.1857	0.1874	0.1891	79
11	0.1908	0.1925	0.1942	0.1959	0.1977	0.1994	0.2011	0.2028	0.2045	0.2062	78
12	0.2079	0.2096	0.2113	0.2130	0.2147	0.2164	0.2181	0.2198	0.2215	0.2233	77
13	0.2250	0.2267	0.2284	0.2300	0.2317	0.2334	0.2351	0.2368	0.2385	0.2402	76
14	0.2419	0.2436	0.2453	0.2470	0.2487	0.2504	0.2521	0.2538	0.2554	0.2571	75
15	0.2588	0.2605	0.2622	0.2639	0.2656	0.2672	0.2689	0.2706	0.2723	0.2740	74
16	0.2756	0.2773	0.2790	0.2807	0.2823	0.2840	0.2857	0.2874	0.2890	0.2907	73
17	0.2924	0.2940	0.2957	0.2974	0.2990	0.3007	0.3024	0.3040	0.3057	0.3074	72
18	0.3090	0.3107	0.3123	0.3140	0.3156	0.3173	0.3190	0.3206	0.3223	0.3239	71
19	0.3256	0.3272	0.3289	0.3305	0.3322	0.3338	0.3355	0.3371	0.3387	0.3404	70
20	0.3420	0.3437	0.3453	0.3469	0.3486	0.3502	0.3518	0.3535	0.3551	0.3567	69
21	0.3584	0.3600	0.3616	0.3633	0.3649	0.3665	0.3681	0.3697	0.3714	0.3730	68
22	0.3746	0.3762	0.3778	0.3795	0.3811	0.3827	0.3843	0.3859	0.3875	0.3891	67
23	0.3907	0.3923	0.3939	0.3955	0.3971	0.3987	0.4003	0.4019	0.4035	0.4051	66
24	0.4067	0.4083	0.4099	0.4115	0.4131	0.4147	0.4163	0.4179	0.4195	0.4210	65
25	0.4226	0.4242	0.4258	0.4274	0.4289	0.4305	0.4321	0.4337	0.4352	0.4368	64
26	0.4384	0.4399	0.4415	0.4431	0.4446	0.4462	0.4478	0.4493	0.4509	0.4524	63
27	0.4540	0.4555	0.4571	0.4586	0.4602	0.4617	0.4633	0.4648	0.4664	0.4679	62
28	0.4695	0.4710	0.4726	0.4741	0.4756	0.4772	0.4787	0.4802	0.4818	0.4833	61
29	0.4848	0.4863	0.4879	0.4894	0.4909	0.4924	0.4939	0.4955	0.4970	0.4985	60
30	0.5000	0.5015	0.5030	0.5045	0.5060	0.5075	0.5090	0.5105	0.5120	0.5135	59
31	0.5150	0.5165	0.5180	0.5195	0.5210	0.5225	0.5240	0.5255	0.5270	0.5284	58
32	0.5299	0.5314	0.5329	0.5344	0.5358	0.5373	0.5388	0.5402	0.5417	0.5432	57
33	0.5446	0.5461	0.5476	0.5490	0.5505	0.5519	0.5534	0.5548	0.5563	0.5577	56
34	0.5592	0.5606	0.5621	0.5635	0.5650	0.5664	0.5678	0.5693	0.5707	0.5721	55
35	0.5736	0.5750	0.5764	0.5779	0.5793	0.5807	0.5821	0.5835	0.5850	0.5864	54
36	0.5878	0.5892	0.5906	0.5920	0.5934	0.5948	0.5962	0.5976	0.5990	0.6004	53
37	0.6018	0.6032	0.6046	0.6060	0.6074	0.6088	0.6101	0.6115	0.6129	0.6143	52
38	0.6157	0.6170	0.6184	0.6198	0.6211	0.6225	0.6239	0.6252	0.6266	0.6280	51
39	0.6293	0.6307	0.6320	0.6334	0.6347	0.6361	0.6374	0.6388	0.6401	0.6414	50
40	0.6428	0.6441	0.6455	0.6468	0.6481	0.6494	0.6508	0.6521	0.6534	0.6547	49
41	0.6561	0.6574	0.6587	0.6600	0.6613	0.6626	0.6639	0.6652	0.6665	0.6678	48
42	0.6691	0.6704	0.6717	0.6730	0.6743	0.6756	0.6769	0.6782	0.6794	0.6807	47
43	0.6820	0.6833	0.6845	0.6858	0.6871	0.6884	0.6896	0.6909	0.6921	0.6934	46
44	0.6947	0.6959	0.6972	0.6984	0.6997	0.7009	0.7022	0.7034	0.7046	0.7059	45
	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	Deg

* From Knowlton, A. E. (ed.), "Standard Handbook for Electrical Engineers," 9th ed., McGraw-Hill, 1957.