

APPENDIX A

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TABLE I.—Specific resistance and temperature co-efficient

Material.	Specific resistance at 59° F. = 15° C.			Temperature coefficient.		Resistance compared with copper (approx.)
	Microhms per centimetre cube.	Microhms per inch cube.	Ohms per mil-foot.	Per degree Cent.	Per degree Fahr.	
Metals :—						
Silver, annealed	1.557	0.613	9.36	.00377	0.210	0.92
Copper, pure	1.66	0.654	10.0	.0041	0.23	0.98
Copper, annealed	1.692	0.666	10.18	.00401	0.223	1.0
Copper, hard drawn	1.724	0.679	10.37	.00393	0.218	1.02
Aluminium	2.78	1.09	16.70	.0040	0.22	1.65
Tungsten	4.8	1.9	29.0	.0047	0.26	2.84
Zinc	6.0	2.4	36.0	.0038	0.21	3.55
Tin	11.0	4.3	66.0	.0040	0.22	6.5
Platinum	11.54	4.54	69.4	.0036	0.20	6.82
Nickel (commercial)	11.8	4.6	71.0	.0027	0.15	7.0
Iron telegraph wire.. ..	12.2	4.8	73.4	.0057	0.32	7.2
Lead	21.7	8.55	130.0	.0039	0.22	12.8
Mercury	95.4	37.56	573.0	.0009	0.05	56.0
Alloys :—						
Platinum silver (a)	24.2	9.53	145	.0003	0.015	14.3
German silver (b)	27	10.6	160	.0004	0.02	16.0
German silver (c)	30	11.8	180	.0004	0.02	17.7
Platinoid (d)	42	16.5	250	.0002	0.01	24.8
Manganin (e)	44	17.3	260	Negligible		26.0
Eureka (f)	49	19.3	295	Negligible		28.0
Carbon :—						
Graphite	3,000	1,200	18,000	—0.0005	—0.03	—
Gas retort and lamp filament	4,000	1,600	24,000	—0.0005	—0.03	—
	7,000	2,800	42,000			

(a) 67 per cent. platinum, 33 per cent. silver.

(b) 62 per cent. copper, 15 per cent. nickel, 22 per cent. zinc.

(c) 50 per cent. copper, 30 per cent. nickel, 20 per cent. zinc.

(d) German silver (b) + 1 per cent. tungsten.

(e) 84 per cent. copper, 12 per cent. manganin, 4 per cent. nickel.

(f) 60 per cent. copper, 40 per cent. nickel.

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TABLE II.—Properties of insulating materials

Material.	Specific resistance ohms per centimetre cube.	Dielectric strength volts per mil.	Permittivity.
Asbestos	16×10^4	100 to 150	—
Bakelite	10^5 to 10^7	200 to 800	4 to 8
Celluloid	7×10^4	300 to 500	1.2 to 2.6
Cotton, varnished	4×10^4	270 to 350	3
Ebonite	10^8 to 10^{12}	500 to 1,000	2.5 to 3.5
Empire Cloth	4×10^8	500 to 1,500	4 to 6
Fibre, red	100 to 5,000	150 to 300	—
Glass	10^7 to 10^9	200 to 250	5 to 9
Guttapercha	4×10^8	200 to 500	3 to 4.5
Marble	10^3 to 10^5	160	8.3
Mica	10^{10} to 10^{11}	500 to 1,500	5 to 8
Micanite	5×10^8	400 to 1,000	—
Paper, dry	10^8	150 to 300	1.5 to 2.5
Paper, impregnated	10^8	500 to 1,200	2.5 to 4.0
Paraffin wax	4×10^{12}	300	2.0 to 2.5
Porcelain	10^8 to 10^9	150 to 300	4 to 7
Press palm	10^4	200 to 250	—
Quartz	2×10^8	—	2.5 to 4.5
Resin	5×10^{10}	280	2.6
Rubber, pure	Up to 10^{16}	500 to 700	2.2 to 2.4
Rubber, vulcanised	5×10^9	400 to 550	3.0 to 3.5
Shellac	5×10^9	40	3.0 to 3.5
Slate	7.5×10^3	30	6 to 7
Sulphur	10^8 to 10^{11}	—	2.5 to 3.5
Wood	10^5	10 to 20	2.5 to 5.0
Glycerine	—	—	39
Paraffin oil	10^8	220	4.7

Note.—The properties of insulating materials vary so much with temperature, moisture content, and method of manufacture that the above values can only be regarded as approximate.

TABLE III.—Properties of metals

Material.	Specific heat.	Melting point degrees Cent.	Specific gravity.	Weight lb. per cubic in.
Aluminium	.2122	600	2.6	.093
Copper	.0933	1,054	8.8	.32
Iron	.1124	1,600	7.8	.27
Lead	.0315	326	11.3	.41
Mercury	.0385	—40	13.6	.49
Platinum	.0323	1,775	21.5	.78
Silver	.0570	954	10.5	.38
Tin	.0559	230	7.3	.26
Zinc	.0935	412	7.2	.26

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TABLE IV.—Annealed copper wire

s.w.g.	Diameter.		Sectional area.		Lb. per 1,000 yards.	Ohms per 1,000 yards (15° C.)
	inch.	m.m.	Sq. inch.	Sq. m.m.		
0	.324	8.23	.08245	53.19	953.4	.2909
1	.300	7.62	.07069	45.60	817.6	.3393
2	.276	7.01	.05983	38.60	692.0	.4009
3	.252	6.401	.04988	32.18	576.7	.4809
4	.232	5.893	.04227	27.27	488.8	.567
5	.212	5.385	.03530	22.77	408.2	.679
6	.192	4.877	.02895	18.68	334.7	.828
7	.176	4.470	.02433	15.70	281.3	.985
8	.160	4.064	.02011	12.97	232.5	1.192
9	.144	3.658	.01629	10.51	188.4	1.471
10	.128	3.251	.01287	8.303	148.8	1.862
11	.116	2.946	.01057	6.819	122.2	2.268
12	.104	2.642	.008495	5.480	98.24	2.821
13	.092	2.337	.006648	4.289	76.88	3.605
14	.080	2.032	.005027	3.243	58.13	4.768
15	.072	1.829	.004072	2.627	47.09	5.89
16	.064	1.626	.003217	2.075	37.20	7.45
17	.056	1.422	.002463	1.589	28.48	9.73
18	.048	1.219	.001810	1.168	20.93	13.24
19	.040	1.016	.001257	.8109	14.53	19.07
20	.036	.9144	.001018	.6567	11.77	23.54
21	.032	.8128	.000804	.5188	9.301	29.80
22	.028	.7112	.000616	.3973	7.120	38.92
23	.024	.6096	.000452	.2919	5.233	53.0
24	.022	.5588	.000380	.2453	4.392	63.0
25	.020	.5080	.000314	.2027	3.633	76.3
26	.018	.4572	.000254	.1642	2.942	94.2
27	.0164	.4166	.000211	.1363	2.44	113.4
28	.0148	.3759	.000172	.1110	1.989	139.3
29	.0136	.3454	.000145	.09372	1.676	165.0
30	.0124	.3149	.000121	.07791	1.399	198.4
31	.0116	.2946	.000106	.06818	1.222	226.8
32	.0108	.2743	.0000916	.05910	1.059	261.6
33	.0100	.2540	.0000785	.05067	.9083	305.1
34	.0092	.2337	.0000665	.04289	.7688	360.5
35	.0084	.2134	.0000554	.03575	.6406	432.4
36	.0076	.1930	.0000454	.02927	.5249	528
37	.0068	.1727	.0000363	.02343	.4197	660
38	.0060	.1524	.0000283	.01824	.3272	848
39	.0052	.1320	.0000213	.01370	.2454	1130
40	.0048	.1220	.0000181	.01170	.2098	1320
41	.0044	.1118	.0000152	.00985	.1760	1580
42	.004	.1030	.0000126	.00833	.1450	1910
43	.0036	.0910	.0000102	.00650	.1180	2350
44	.0032	.0882	.00000805	.00529	.0940	2970
45	.0028	.0711	.00000615	.00399	.0710	3890
46	.0024	.0609	.00000451	.00259	.0540	5300
47	.002	.0507	.00000314	.00203	.0360	7630
48	.0016	.0406	.00000201	.00130	.0230	11900
49	.0012	.0304	.00000113	.00073	.0013	21100
50	.001	.0254	.00000078	.00051	.0091	30510

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TABLE V.—Conversion of British and Metric units

Units.	C.G.S. to British.	British to C.G.S.
Length {	1 cm. = 0·3937 in. 1 metre = 3·281 ft. 1 kilometre = 0·6214 mile.	1 in. = 2·54 cms. 1 ft. = 30·48 cms. 1 mile = 1609 metres.
Area {	1 sq. cm. = 0·155 sq. in. 1 sq. metre = 10·76 sq. ft.	1 sq. in. = 6·452 sq. cms. 1 sq. ft. = 0·0929 sq. metres.
Volume {	1 cu. cm. = 0·061 cu. in. 1 cu. metre = 35·32 cu. ft.	1 cu. in. = 16·39 cu. cms. 1 cu. ft. = 0·0283 cu. metres.
Mass {	1 gm. = 0·0353 oz. 1 kilogram. = 2·205 lb.	1 oz. = 28·35 gms. 1 lb. = 0·4536 kilogram.

TABLE VI.—Values in absolute units

Electrical quantity.	Practical Unit.	Value in absolute E.M. Units.
Current	Ampere	10^{-1}
Electromotive force, P.D.	Volt	10^8
Resistance	Ohm	10^9
Quantity	Coulomb	10^{-1}
Energy	Joule	10^7
Power	Watt	10^7
Power	Kilowatt	10^{10}
Capacitance	Farad	10^{-9}
Inductance	Henry	10^9

TABLE VII.—Mechanical and Electrical work and power equivalents

N.B.—1 B.Th.U. = amount of heat required to raise 1 lb. of water through 1° F.

Units.	Equivalent values in other units.
1 B.Th.U.	1,055 watt seconds. 778 ft.-lb. 0·252 calorie (kg.d). 108 kilogram-metres. 0·000291 kilowatt hour. 0·000388 H.P. hour. 0·0000667 lb. coal (oxidised). 0·00087 lb. water evaporated at 212° F.
1 B.Th.U. per square foot per min. ..	0·121 watts per square inch. 0·0174 kilowatt. 0·0232 H.P.
1 ft.-lb.	1·36 joule. 0·1383 kilogram-metre. 0·000000377 kilowatt hour. 0·00128 B.Th.U. 0·0000005 H.P. hour.

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TABLE VII.—Mechanical and Electrical work and power equivalents—*contd.*

Units.	Equivalent values in other units.
1 lb. water evaporated at 212° F. ..	0.33 kilowatt hour. 0.44 H.P. hour. 1.140 B.Th.U. 124,200 kilogram-metres. 1,219,000 joules. 887,800 ft.-lb.
1 H.P.	746 watts. 0.746 kilowatts. 33,000 ft.-lb. per minute. 550 ft.-lb. per second. 2,548 B.Th.U. per hour. 42.5 B.Th.U. per minute. 0.71 B.Th.U. per second. 2.25 lb. water evaporated per hour at 212° F.
1 H.P. hour	0.746 kilowatt hour. 1,980,000 ft.-lb. 2,548 B.Th.U. 273,740 kilogram-metres. 2.25 lb. water evaporated at 212° F. 17.2 lb. water raised from 62° to 212° F.
1 Watt	1 joule per second. 0.00134 H.P. 0.001 kilowatt. 3.415 B.Th.U. per hour. 44.25 B.Th.U. per minute. 0.73 ft.-lb. per second. 0.003 lb. of water evaporated per hour.
1 Kilowatt	1,000 watts. 1.34 H.P. 2,655,200 ft.-lb. per hour. 44,253 ft.-lb. per minute. 737.5 ft. lb. per second. 3,415 B.Th.U. per hour. 57.0 B.Th.U. per minute. 0.95 B.Th.U. per second. 3 lb. water evaporated per hour at 212° F.
1 Kilowatt hour	1,000 watt hours. 1.34 H.P. hours. 2,655,200 ft.-lb. 3,600,000 joules. 3,415 B.Th.U. 366,848 kilogram-metres. 3 lb. water evaporated at 212° F. 22.8 lb. water raised from 62° to 212° F.
1 Kilogram-metre	7.23 ft.-lb. 0.0000366 H.P. hour. 0.0000272 kilowatt hour. 0.0092 B.Th.U.
1 Joule	1 watt second. 0.0000278 kilowatt hour. 0.102 kilogram-metre. 0.000947 B.Th.U. 0.73 ft.-lb.

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TABLE VIII.—Skin effect and proximity factors

F = Skin effect factor. G = proximity factor. d = diameter of wire in cm. ρ = Specific resistance in E.M. Units. For copper, $\rho = 1700$ approx., and $z = .1078 d\sqrt{f}$.

z	F	G	z	F	G	z	F	G	z	F	G
0.0	negligible	$\left. \begin{array}{l} z^4 \\ 64 \end{array} \right\}$ 0.00097	2.5	0.175	0.2949	5.0	1.043	0.755	10.0	2.799	1.641
0.1			2.6	0.201	0.3184	5.2	1.114	0.790	11.0	3.151	1.818
0.2			2.7	0.228	0.3412	5.4	1.184	0.826	12.0	3.504	1.995
0.3			2.8	0.256	0.3632	5.6	1.254	0.861	13.0	3.856	2.171
0.4			2.9	0.286	0.3844	5.8	1.324	0.896	14.0	4.209	2.348
0.5			3.0	0.318	0.4049	6.0	1.394	0.932	15.0	4.562	2.525
0.6	0.001	0.00202	3.1	0.351	0.4247	6.2	1.463	0.967	16.0	4.915	2.702
0.7	0.001	0.00373	3.2	0.385	0.4439	6.4	1.533	1.003	17.0	5.268	2.879
0.8	0.002	0.00632	3.3	0.420	0.4626	6.6	1.603	1.038	18.0	5.621	3.056
0.9	0.003	0.01006	3.4	0.456	0.4807	6.8	1.673	1.073	19.0	5.974	3.233
1.0	0.005	0.01519	3.5	0.492	0.4987	7.0	1.743	1.109	20.0	6.328	3.409
1.1	0.008	0.02196	3.6	0.529	0.5160	7.2	1.813	1.144	21.0	6.681	3.586
1.2	0.011	0.03059	3.7	0.566	0.5333	7.4	1.884	1.180	22.0	7.034	3.763
1.3	0.015	0.04127	3.8	0.603	0.5503	7.6	1.954	1.216	23.0	7.388	3.940
1.4	0.020	0.0541	3.9	0.640	0.5673	7.8	2.024	1.251	24.0	7.741	4.117
1.5	0.026	0.0691	4.0	0.678	0.5842	8.0	2.094	1.287	25.0	8.094	4.294
1.6	0.033	0.0863	4.1	0.715	0.601	8.2	2.165	1.322	30.0	9.86	5.177
1.7	0.042	0.1055	4.2	0.752	0.618	8.4	2.235	1.357	40.0	13.40	6.946
1.8	0.052	0.1265	4.3	0.789	0.635	8.6	2.306	1.393	50.0	16.93	8.713
1.9	0.064	0.1489	4.4	0.826	0.652	8.8	2.376	1.428	60.0	20.46	10.48
2.0	0.078	0.1724	4.5	0.863	0.669	9.0	2.446	1.464	70.0	24.00	12.25
2.1	0.094	0.1967	4.6	0.899	0.686	9.2	2.517	1.499	80.0	27.54	14.02
2.2	0.111	0.2214	4.7	0.935	0.703	9.4	2.587	1.534	90.0	31.07	15.78
2.3	0.131	0.2462	4.8	0.971	0.720	9.6	2.658	1.570	100.0	34.61	17.55
2.4	0.152	0.2708	4.9	1.007	0.738	9.8	2.728	1.605	>100	$\frac{\sqrt{2z}-3}{4}$	$\frac{\sqrt{2z}-1}{8}$
2.5	0.175	0.2949	5.0	1.043	0.755	10.0	2.799	1.641			

TABLE IX.—Space factor, J

For use in the formula $R_{ac} = R_{dc} \left(1 + F + \frac{z G c^2}{1 - J \frac{d^2}{c^2}} \right)$ (Chapter V).

(i) Currents in adjacent wires in the same direction.

z	0	1	2	3	4	5	>>5
J	0.042	0.033	-0.056	-0.152	-0.176	-0.185	-0.250

(ii) Currents in adjacent wires in opposite directions.

z	0	1	2	3	4	5	>>5
J	0.042	0.053	0.169	0.348	0.466	0.53	0.750

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TABLE X.—Factor u . (Chapter V)

u depends upon the number of wires running parallel, as under.

No. of wires	2	4	6	8	10
u	1.0	1.8	2.16	2.37	2.51
No. of wires	12	16	24	32	∞
u	2.61	2.74	2.91	3.0	$\frac{\pi^2}{3}$

The above values are applicable to single-layer solenoids or pancake coils in which the winding space is small compared with the radius of the coil.

For single-layer solenoids of many turns, well spaced, the following Table may be used.

D = diameter of coil.			l = length of coil.			
$\frac{l}{D}$	0	0.2	0.4	0.6	0.8	1.0
u	3.29	3.63	4.06	4.50	4.93	5.29
$\frac{l}{D}$	2	4	6	8	10	∞
u	6.58	7.74	8.38	8.73	8.9	9.87

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TABLE XI.—*Number of turns per square inch of winding space*

s.w.g.	Double cotton covered.	Single cotton covered.	Double silk covered.	Single silk covered.	Enamel. Covered.
10	49	54	57	58	59
11	59	65	69	71	72
12	72	80	85	87	89
13	89	100	107	111	114
14	113	129	140	145	150
15	135	156	171	178	185
16	173	198	213	223	234
17	216	252	274	287	304
18	297	343	377	400	403
19	400	472	528	567	587
20	472	567	641	692	720
21	567	692	793	865	910
22	692	865	1,110	1,110	1,173
23	865	1,110	1,320	1,480	1,575
24	977	1,280	1,600	1,770	1,880
25	1,110	1,480	1,890	2,110	2,250
26	1,280	1,740	2,270	2,560	2,770
27	1,450	1,980	2,670	3,010	3,300
28	1,630	2,310	3,160	3,650	4,100
29	1,810	2,600	3,600	4,580	4,770
30	1,990	2,950	4,500	5,180	5,660

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