

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$R = abc/4\Delta$$

*
ORIGINAL
EDITION



Orient Longman
Clark's Tables

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CLARK'S TABLES

$$a^2 = b^2 + c^2 - 2bc \cos A$$

*
ORIGINAL
EDITION

Science Data Book

	0	1	2	3	4
64	8062	8069	8075	8082	8089
65	8129	8136	8142	8149	8156
66	8195	8202	8209	8215	8222
67	8261	8267	8274	8280	8287

$$R = abc/4\Delta$$

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Logarithms

2

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
10	0000	0043	0088	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1108	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2088	2105	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3019	3032	3054	3075	3098	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4055	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4168	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5480	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5788	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	8	9
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	6	7	8	9
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	5	6	7	8	9
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	4	5	6	7	8	9
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

Logarithms

3

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	5	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	4	5	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	4	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	3	4	4	5
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	3	4	4	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	3	4	4	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	3	4	4	5
74	8692	8697	8703	8709	8716	8722	8729	8736	8742	8749	1	1	2	2	3	3	4	4	5
75	8751	8756	8762	8768	8774	8781	8787	8793	8799	8802	1	1	2	2	3	3	4	4	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	4	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2						

Antilogarithms

4

	Mean Differences									
	0	1	2	3	4	5	6	7	8	9
	12	3	4	5	6	7	8	9	0	
.00	1000	1002	1005	1007	1009	1012	1014	1016	1018	1021
.01	1023	1028	1030	1033	1035	1038	1040	1042	1045	1048
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069
.03	1072	1074	1076	1079	1081	1084	1088	1089	1091	1094
.04	1098	1099	1102	1104	1107	1109	1112	1114	1117	1119
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285
.11	1288	1291	1294	1297	1300	1303	1308	1309	1312	1315
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476
.17	1479	1483	1486	1489	1493	1498	1500	1503	1507	1510
.18	1514	1517	1521	1524	1526	1531	1535	1538	1542	1545
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581
.20	1585	1589	1592	1598	1600	1603	1607	1611	1614	1618
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694
.23	1698	1702	1703	1710	1714	1718	1722	1726	1730	1734
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991
.30	1995	2000	2004	2008	2014	2018	2023	2028	2032	2037
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155

Antilogarithms

5

	Mean Differences									
	0	1	2	3	4	5	6	7	8	9
	12	3	4	5	6	7	8	9	0	
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622
.56	3631	3639	3648	3656	3664	3673	3681	3689	3698	3707
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793
.58	3802	3811	3819	3828	3837	3846	3855	3873	3882	3891
.59	3890	3898	3908	3917	3926	3936	3945	3953	3972	3981
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159
.62	4169	4178	4188	4198	4207	4217	4226	4236	4246	4256
.63	4266	4276	4285	4295	4303	4315	4325	4335	4345	4355
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4456
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667
.67	4677	4686	4699	4710	4721	4732	4742	4753	4764	4775
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887
.69	4898	4909	4920	4932	4943	4955	4965	4977	4989	5000
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063
.85	7079	7098	7112	7129	7145	7161	7178	7194	7211	7228
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9098
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977

Natural Sines

6

	0°	0' 0°	6' 0°	12' 0°	18' 0°	24' 0°	30' 0°	36' 0°	42' 0°	48' 0°	54' 0°	Mean Differences				
												1' 0°	2' 0°	3' 0°	4' 0°	5' 0°
0°	0.0000	0.017	0.035	0.052	0.070	0.087	0.105	0.122	0.140	0.157	0.175	3	6	9	12	15
1°	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332	0.0350	3	6	9	12	15
2°	0.0349	0.0366	0.0384	0.0401	0.0419	0.0436	0.0454	0.0471	0.0488	0.0506	0.0524	3	6	9	12	15
3°	0.0523	0.0541	0.0558	0.0576	0.0593	0.0610	0.0628	0.0645	0.0663	0.0680	0.0698	3	6	9	12	15
4°	0.0698	0.0715	0.0732	0.0750	0.0767	0.0785	0.0802	0.0819	0.0837	0.0854	0.0872	3	6	9	12	15
5°	0.0872	0.0889	0.0906	0.0924	0.0941	0.0958	0.0976	0.0993	0.1011	0.1028	0.1045	3	6	9	12	14
6°	0.1045	0.1063	0.1080	0.1097	0.1115	0.1132	0.1149	0.1167	0.1184	0.1201	0.1219	3	6	9	12	14
7°	0.1219	0.1236	0.1253	0.1271	0.1288	0.1305	0.1323	0.1340	0.1357	0.1374	0.1392	3	6	9	12	14
8°	0.1392	0.1409	0.1426	0.1444	0.1461	0.1478	0.1495	0.1513	0.1530	0.1547	0.1564	3	6	9	12	14
9°	0.1564	0.1582	0.1599	0.1616	0.1633	0.1650	0.1668	0.1685	0.1702	0.1719	0.1736	3	6	9	11	14
10°	0.1736	0.1754	0.1771	0.1788	0.1805	0.1822	0.1840	0.1857	0.1874	0.1891	0.1908	3	6	9	11	14
11°	0.1908	0.1925	0.1942	0.1959	0.1977	0.1994	0.2011	0.2028	0.2045	0.2062	0.2079	3	6	9	11	14
12°	0.2079	0.2096	0.2113	0.2130	0.2147	0.2164	0.2181	0.2198	0.2215	0.2233	0.2250	3	6	9	11	14
13°	0.2250	0.2267	0.2284	0.2300	0.2317	0.2334	0.2351	0.2368	0.2385	0.2402	0.2419	3	6	8	11	14
14°	0.2419	0.2436	0.2453	0.2470	0.2487	0.2504	0.2521	0.2538	0.2554	0.2571	0.2588	3	6	8	11	14
15°	0.2588	0.2605	0.2622	0.2639	0.2656	0.2672	0.2689	0.2706	0.2723	0.2740	0.2756	3	6	8	11	14
16°	0.2756	0.2773	0.2790	0.2807	0.2823	0.2840	0.2857	0.2874	0.2890	0.2907	0.2924	3	6	8	11	14
17°	0.2924	0.2940	0.2957	0.2974	0.2990	0.3007	0.3024	0.3040	0.3057	0.3074	0.3090	3	6	8	11	14
18°	0.3090	0.3107	0.3123	0.3140	0.3156	0.3173	0.3190	0.3206	0.3223	0.3239	0.3256	3	6	8	11	14
19°	0.3256	0.3272	0.3289	0.3305	0.3322	0.3338	0.3355	0.3371	0.3387	0.3404	0.3420	3	5	8	11	14
20°	0.3420	0.3437	0.3453	0.3469	0.3486	0.3502	0.3518	0.3535	0.3551	0.3567	0.3584	3	5	8	11	14
21°	0.3584	0.3600	0.3616	0.3633	0.3649	0.3665	0.3681	0.3697	0.3714	0.3730	0.3746	3	5	8	11	14
22°	0.3746	0.3762	0.3778	0.3795	0.3811	0.3827	0.3843	0.3859	0.3875	0.3891	0.3907	3	5	8	11	14
23°	0.3907	0.3923	0.3939	0.3955	0.3971	0.3987	0.4003	0.4019	0.4035	0.4051	0.4067	3	5	8	11	14
24°	0.4067	0.4083	0.4099	0.4115	0.4131	0.4147	0.4163	0.4179	0.4195	0.4210	0.4226	3	5	8	11	13
25°	0.4226	0.4242	0.4258	0.4274	0.4289	0.4305	0.4321	0.4337	0.4352	0.4368	0.4384	3	5	8	11	13
26°	0.4384	0.4399	0.4415	0.4431	0.4446	0.4462	0.4478	0.4493	0.4509	0.4524	0.4540	3	5	8	10	13
27°	0.4540	0.4555	0.4571	0.4586	0.4602	0.4617	0.4633	0.4648	0.4664	0.4679	0.4695	3	5	8	10	13
28°	0.4695	0.4710	0.4726	0.4741	0.4756	0.4772	0.4787	0.4802	0.4818	0.4833	0.4848	3	5	8	10	13
29°	0.4848	0.4863	0.4879	0.4894	0.4909	0.4924	0.4939	0.4955	0.4970	0.4985	0.5000	3	5	8	10	13
30°	0.5000	0.5015	0.5030	0.5045	0.5060	0.5075	0.5090	0.5105	0.5120	0.5135	0.5150	3	5	8	10	13
31°	0.5150	0.5165	0.5180	0.5195	0.5210	0.5225	0.5240	0.5255	0.5270	0.5284	0.5299	2	5	7	10	12
32°	0.5299	0.5314	0.5329	0.5344	0.5358	0.5373	0.5388	0.5402	0.5417	0.5432	0.5446	2	5	7	10	12
33°	0.5446	0.5461	0.5476	0.5490	0.5505	0.5519	0.5534	0.5548	0.5563	0.5577	0.5592	2	5	7	10	12
34°	0.5592	0.5606	0.5621	0.5635	0.5650	0.5664	0.5678	0.5693	0.5707	0.5721	0.5736	2	5	7	10	12
35°	0.5736	0.5750	0.5764	0.5779	0.5793	0.5807	0.5821	0.5835	0.5850	0.5864	0.5878	2	5	7	9	12
36°	0.5878	0.5892	0.5906	0.5920	0.5934	0.5948	0.5962	0.5976	0.5990	0.6004	0.6018	2	5	7	9	11
37°	0.6018	0.6032	0.6046	0.6060	0.6074	0.6088	0.6101	0.6115	0.6129	0.6143	0.6157	2	5	7	9	11
38°	0.6157	0.6170	0.6184	0.6198	0.6211	0.6225	0.6239	0.6252	0.6266	0.6280	0.6294	2	5	7	9	11
39°	0.6293	0.6307	0.6320	0.6334	0.6347	0.6361	0.6374	0.6388	0.6401	0.6414	0.6428	2	4	7	9	11
40°	0.6428	0.6441	0.6455	0.6468	0.6481	0.6494	0.6508	0.6521	0.6534	0.6547	0.6562	2	4	7	9	11
41°	0.6561	0.6574	0.6587	0.6600	0.6613	0.6626	0.6639	0.6652	0.6665	0.6678	0.6691	2	4	7	9	11
42°	0.6691	0.6704	0.6717	0.6730	0.6743	0.6756	0.6769	0.6782	0.6794	0.6807	0.6820	2	4	6	9	11
43°	0.6820	0.6833	0.6845	0.6858	0.6871	0.6884	0.6896	0.6909	0.6921	0.6934	0.6947	2	4	6	8	11
44°	0.6947	0.6959	0.6972	0.6984	0.6997	0.7009	0.7022	0.7034	0.7046	0.7059	0.7072	2	4	6	8	10

Natural Sines

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	0°	0' 0°	6' 0°	12' 0°	18' 0°	24' 0°	30' 0°	36' 0°	42' 0°	48' 0°	54' 0°	Mean Differences					
												1' 0°	2' 0°	3' 0°	4' 0°	5' 0°	
45°	0.7071	0.7083	0.7096	0.7108	0.7120	0.7133	0.7145	0.7157	0.7169	0.7181	0.7194	2	4	6	8	10	
46°	0.7193	0.7206	0.7218	0.7230	0.7242	0.7254	0.7266	0.7278	0.7290	0.7302	0.7314	2	4	6	8	10	
47°	0.7314	0.7325	0.7337	0.7349	0.7361	0.7373	0.7385	0.7397	0.7408	0.7420	0.7432	2	4	6	8	10	
48°	0.7431	0.7443	0.7455	0.7467	0.7479	0.7491	0.7503	0.7515	0.7527	0.7539	0.7551	2	4	6	8	10	
49°	0.7547	0.7559	0.7571	0.7583	0.7595	0.7607	0.7619	0.7631	0.7643	0.7655	0.7667	2	4	6	8	10	
50°	0.7660	0.7672	0.7683	0.7695	0.7707	0.7719	0.7731	0.7743	0.7755	0.7767	0.7779	0.7791	2	4	6	8	10
51°	0.7771	0.7782	0.7793	0.7804	0.7815	0.7826	0.7837	0.7848	0.7859	0.7870	0.7881	2	4	6	8	10	
52°	0.7880	0.7891	0.7902	0.7912	0.7923	0.7934	0.7944	0.7955	0.7965	0.7976	0.7987	0.7998	2	4	6	8	10
53°	0.7986	0.8007	0.8018	0.8028	0.8039	0.8050	0.8069	0.8080	0.8091	0.8102	0.8113	0.8124	2	4	6	8	10
54°	0.8090	0.8100	0.8111	0.8121	0.8131	0.8141	0.8151	0.8161	0.8171	0.8181	0.8191	0.8202	2	4	6	8	10
55°	0.8192	0.8202	0.8211	0.8221	0.8231	0.8241	0.8251	0.8261	0.8271	0.8281	0.8291	0.8302	2	4	6	8	10
56°	0.8290	0.8300	0.8310	0.8320	0.8330	0.8340	0.8350	0.8360	0.8370	0.8380	0.8390	0.8402	2	4	6	8	10
57°	0.8387	0.8396	0.8405	0.8415	0.8425	0.8434	0.8443	0.8453	0.8463	0.8473	0.8483	0.8493	2	4	6	8	10
58°	0.8480	0.8490	0.8499	0.8508	0.8517	0.8526	0.8536	0.8545	0.8554	0.8563	0.8573	0.8582	2	4	6	8	10
59°	0.8572	0.8581	0.8590	0.8599	0.8607	0.8616	0.8625	0.8634	0.8643	0.8652	0.8661	0.8670	2	4	6	8	10
60°	0.8660	0.8669	0.8678	0.8686	0.8695	0.8704	0.8712	0.8721	0.8730	0.8739	0.8748	0.8757	2	4	6	8	10
61°	0.8746	0.8755	0.8763	0.8771	0.8780	0.8788	0.8796	0.8805	0.8813	0.8821	0.8830	0.8839	2	4	6	8	10
62°	0.8829	0.8838	0.8846	0.8854	0.8862	0.8870	0.8878	0.8886	0.8894	0.8902	0.8910	0.8					

Natural Cosines

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	SUBTRACT Mean Differences											
	0° 0°-0°	8° 0°-1°	12° 0°-2°	18° 0°-3°	24° 0°-4°	30° 0°-5°	36° 0°-6°	42° 0°-7°	48° 0°-8°	54° 0°-9°	1' 2' 3' 4' 5'	
0°	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0 0 0 0 0	
1	0.9998	0.9998	0.9998	0.9997	0.9997	0.9997	0.9996	0.9996	0.9995	0.9995	0 0 0 0 0	
2	0.9994	0.9993	0.9993	0.9992	0.9991	0.9990	0.9990	0.9989	0.9988	0.9987	0 0 0 1 1	
3	0.9988	0.9988	0.9988	0.9983	0.9982	0.9981	0.9980	0.9979	0.9978	0.9977	0 0 1 1 1	
4	0.9978	0.9974	0.9973	0.9972	0.9971	0.9969	0.9968	0.9966	0.9965	0.9963	0 0 1 1 1	
5	0.9962	0.9960	0.9959	0.9957	0.9956	0.9954	0.9952	0.9951	0.9949	0.9947	0 1 1 1 2	
6	0.9945	0.9943	0.9942	0.9940	0.9938	0.9938	0.9934	0.9932	0.9930	0.9928	0 1 1 1 2	
7	0.9925	0.9923	0.9921	0.9919	0.9917	0.9914	0.9912	0.9910	0.9907	0.9905	0 1 1 2 2	
8	0.9903	0.9900	0.9899	0.9895	0.9893	0.9890	0.9888	0.9885	0.9882	0.9880	0 1 1 2 2	
9	0.9877	0.9874	0.9871	0.9869	0.9866	0.9863	0.9860	0.9857	0.9854	0.9851	0 1 1 2 2	
10°	0.9848	0.9845	0.9842	0.9839	0.9836	0.9833	0.9829	0.9826	0.9823	0.9820	1 1 2 2 3	
11	0.9816	0.9813	0.9810	0.9808	0.9803	0.9799	0.9796	0.9792	0.9789	0.9785	1 1 2 2 3	
12	0.9781	0.9778	0.9774	0.9770	0.9767	0.9763	0.9759	0.9755	0.9751	0.9748	1 1 2 3 3	
13	0.9744	0.9740	0.9736	0.9732	0.9728	0.9724	0.9720	0.9715	0.9711	0.9707	1 1 2 3 4	
14	0.9703	0.9699	0.9694	0.9690	0.9688	0.9681	0.9677	0.9673	0.9668	0.9664	1 1 2 3 4	
15	0.9659	0.9655	0.9650	0.9646	0.9641	0.9636	0.9632	0.9627	0.9622	0.9617	1 2 3 4	
16	0.9613	0.9608	0.9603	0.9598	0.9593	0.9588	0.9583	0.9578	0.9573	0.9568	1 2 2 3 4	
17	0.9563	0.9558	0.9553	0.9548	0.9542	0.9537	0.9532	0.9527	0.9521	0.9518	1 2 3 3 4	
18	0.9511	0.9505	0.9500	0.9494	0.9489	0.9483	0.9478	0.9472	0.9466	0.9461	1 2 3 4 5	
19	0.9455	0.9449	0.9444	0.9438	0.9432	0.9426	0.9421	0.9415	0.9409	0.9403	1 2 3 4 5	
20°	0.9397	0.9391	0.9385	0.9379	0.9373	0.9367	0.9361	0.9354	0.9348	0.9342	1 2 3 4 5	
21	0.9338	0.9330	0.9323	0.9317	0.9311	0.9304	0.9298	0.9291	0.9285	0.9278	1 2 3 4 5	
22	0.9272	0.9265	0.9259	0.9252	0.9249	0.9239	0.9232	0.9225	0.9219	0.9212	1 2 3 4 6	
23	0.9205	0.9198	0.9191	0.9184	0.9178	0.9171	0.9164	0.9157	0.9150	0.9143	1 2 3 5 6	
24	0.9135	0.9128	0.9121	0.9114	0.9107	0.9101	0.9092	0.9085	0.9078	0.9070	1 2 4 5 6	
25	0.9063	0.9056	0.9048	0.9041	0.9033	0.9026	0.9018	0.9011	0.9003	0.8996	1 3 4 5 6	
26	0.8988	0.8980	0.8973	0.8965	0.8957	0.8949	0.8942	0.8934	0.8926	0.8918	1 3 4 5 6	
27	0.8910	0.8902	0.8894	0.8886	0.8878	0.8870	0.8862	0.8854	0.8846	0.8838	1 3 4 5 7	
28	0.8829	0.8821	0.8813	0.8805	0.8796	0.8788	0.8780	0.8771	0.8763	0.8755	1 3 4 6 7	
29	0.8746	0.8738	0.8729	0.8721	0.8712	0.8704	0.8695	0.8688	0.8680	0.8678	1 3 4 6 7	
30°	0.8660	0.8652	0.8643	0.8634	0.8624	0.8616	0.8607	0.8599	0.8590	0.8581	1 3 4 6 7	
31	0.8572	0.8563	0.8554	0.8545	0.8536	0.8526	0.8517	0.8508	0.8499	0.8490	2 3 5 6 8	
32	0.8480	0.8471	0.8462	0.8453	0.8443	0.8434	0.8425	0.8415	0.8406	0.8396	2 3 5 6 8	
33	0.8387	0.8377	0.8368	0.8358	0.8348	0.8338	0.8329	0.8320	0.8310	0.8300	2 3 5 6 8	
34	0.8290	0.8281	0.8271	0.8261	0.8251	0.8241	0.8231	0.8221	0.8211	0.8202	2 3 5 7 8	
35	0.8192	0.8181	0.8171	0.8161	0.8151	0.8141	0.8131	0.8121	0.8111	0.8100	2 3 5 7 8	
36	0.8090	0.8080	0.8070	0.8059	0.8049	0.8039	0.8028	0.8018	0.8007	0.7997	2 3 5 7 9	
37	0.7988	0.7978	0.7965	0.7955	0.7944	0.7934	0.7923	0.7912	0.7902	0.7891	2 4 5 7 9	
38	0.7880	0.7869	0.7859	0.7848	0.7837	0.7828	0.7815	0.7804	0.7793	0.7782	2 4 5 7 9	
39	0.7771	0.7760	0.7749	0.7738	0.7727	0.7716	0.7705	0.7694	0.7683	0.7672	2 4 6 7 9	
40°	0.7660	0.7649	0.7638	0.7627	0.7615	0.7604	0.7593	0.7581	0.7570	0.7559	2 4 6 8 9	
41	0.7547	0.7538	0.7524	0.7513	0.7501	0.7490	0.7478	0.7468	0.7455	0.7443	2 4 6 8 10	
42	0.7431	0.7420	0.7408	0.7398	0.7373	0.7361	0.7349	0.7337	0.7325	0.7313	2 4 6 8 10	
43	0.7314	0.7302	0.7290	0.7278	0.7266	0.7254	0.7242	0.7230	0.7218	0.7206	2 4 6 8 10	
44	0.7193	0.7181	0.7169	0.7157	0.7145	0.7133	0.7120	0.7108	0.7098	0.7083	2 4 6 8 10	

Natural Cosines

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	SUBTRACT Mean Differences											
	0° 0°-0°	8° 0°-1°	12° 0°-2°	18° 0°-3°	24° 0°-4°	30° 0°-5°	36° 0°-6°	42° 0°-7°	48° 0°-8°	54° 0°-9°	1' 2' 3' 4' 5'	
45°	0.7071	7059	7046	7034	7022	7009	6997	6984	6972	6959	2 4 6 8 10	
46	0.6947	6934	6921	6909	6886	6884	6871	6858	6845	6833	2 4 6 8 11	
47	0.6820	6807	6794	6782	6769	6756	6743	6730	6717	6704	2 4 6 8 11	
48	0.6691	6678	6665	6652	6639	6626	6613	6600	6587	6574	2 4 6 7 9 11	
49	0.6561	6547	6534	6521	6508	6494	6481	6468	6455	6441	2 4 6 7 9 11	
50°	0.6428	6414	6401	6388	6374	6361	6347	6334	6320	6307	2 4 6 7 9 11	
51	0.6293	6280	6266	6252	6229	6211	6198	6184	6170	6157	2 5 7 9 11	
52	0.6157	6143	6129	6115	6101	6088	6074	6060	6046	6032	2 5 7 9 12	
53	0.6018	6004	5990	5976	5954	5934	5920	5906	5892	5879	2 5 7 9 12	
54	0.5873	5864	5850	5835	5821	5807	5793	5784	5760	5746	2 5 7 9 12	
55	0.5739	5721	5707	5693	5678	5664	5650	5635	5621	5606	2 5 7 9 12	
56	0.5592	5577	5563	5548	5534	5519	5505	5490	5476	5461	2 5 7 10 12	
57	0.5448	5432	5417	5402	5388	5373	5358	5344	5329	5314	2 5 7 10 12	
58	0.5299	5284	5270	5257	5240	5226	5210	5196	5180	5166	2 5 7 10 12	
59	0.5150	5135	5120	5105	5090	5075	5060	5045	5030	5015	2 5 8 10 12	
60°	0.5000	4965	4970	4955	4938	4924	4909	4894	4878	4863	3 5 8 10 12	
61	0.4848	4833	4818	4802	4787	4774	4759	4741	4726	4710	3 5 8 10 12	
62	0.4695	4679	4664	4648	4633	4617	4602	4589	4571	4555	3 5 8 10 12	
63	0.4540	4524	4509	4493	4478	4462	4446	4431	4415	4399	3 5 8 10 12	
64	0.4384	4368	4352	4337	4321	4305	4289	4274	4258	4242	3 5 8 10 12	
65	0.4226	4210	4195	4179	4163	4147	4131	4115	4099	4083	3 5 8 11 14	
66	0.4067	4051	4035	4019	4003	3987	3971	3955	3939	3923	3 5 8 11 14	
67	0.3907	3891	3875	3859	3843	3827	3811	3795	3778	3762	3 5 8 11 14	
68	0.3748	3730	3714	3697	3681	3665	3649	3633	3616	3600	3 5 8 11 14	
69	0.3584	3567	3551	3535	3518	3502	3486	3469	3453	3437	3 5 8 11 14	
70°	0.3420	3404	3387	3371	3355	3338	3322	3305	3289	3272	3 5 8 11 14	
71	0.3258	3239	3223	3208	3190	3173	3156	3140	3123	3107	3 6 8 11 14	
72	0.3090	3074	3057	3040	3024	3007	2990	2974	2957	2940	3 6 8 11 14	
73	0.2924	2907	2890	2874	2857	2840	2823	2807	2790	2776	3 6 8 11 14	
74	0.2756	2740	2723	2706	2689	2672	2656	2639	2622	2605	3 6 8 11 14	
75	0.2588	2571	2554	2538	2521	2504	2487	2470	2453	2436	3 6 8 11 14	
76	0.2419	2402	2385	2368	2351	2334	2317	2300	2284	2267	3 6 8 11 14	
77	0.2250	2233	2215	2198	2181	2164	2147	2130	2113	2096	3 6 8 11 14	
78	0.2073	2062	2045	2028	2011	1994	1977	1959	1942	1925	3 6 8 11 14	
79	0.1908	1891	1874	1857	1840	1822	1805	1788	1771	1754	3 6 8 11 14	
80°	0.1736	1719	1702	1685	1668	1653	1636	1616	1599	1582	3 6 8 12 14	
81	0.1564	1547	1530	1513	1495	1478	1461	1444	1426	1409	3 6 8 12 14	
82	0.1392	1374	1357	1340	1323	1305	1288	1271	1253	1236	3 6 8 12 14	
83	0.1219	1201	1184	1167	1149	1132	1115	1097	1080	1063	3 6 8 12 14	
84	0.1045	1028	1011</									

Natural Tangents

10

	0°	Mean Differences											
		0' 0°	6' 0' 1°	12' 0' 2°	18' 0' 3°	24' 0' 4°	30' 0' 5°	36' 0' 6°	42' 0' 7°	48' 0' 8°	54' 0' 9°	1' 2' 3' 4' 5'	
	0°	0.0000	0.017	0.035	0.052	0.070	0.087	0.105	0.122	0.140	0.157	3 6 9 12 15	
1	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332	0.0350	3 6 9 12 15	
2	0.0349	0.0367	0.0384	0.0402	0.0419	0.0437	0.0454	0.0472	0.0489	0.0507	0.0525	3 6 9 12 15	
3	0.0524	0.0542	0.0559	0.0577	0.0594	0.0612	0.0629	0.0647	0.0664	0.0682	0.0700	3 6 9 12 15	
4	0.0699	0.0717	0.0734	0.0752	0.0769	0.0787	0.0805	0.0822	0.0840	0.0857	0.0875	3 6 9 12 15	
5	0.0875	0.0892	0.0910	0.0928	0.0945	0.0963	0.0981	0.0998	0.1016	0.1033	0.1051	3 6 9 12 15	
6	0.1051	0.1069	0.1086	0.1104	0.1122	0.1139	0.1157	0.1175	0.1192	0.1209	0.1226	3 6 9 12 15	
7	0.1228	0.1246	0.1263	0.1281	0.1299	0.1317	0.1334	0.1352	0.1370	0.1388	0.1405	3 6 9 12 15	
8	0.1405	0.1423	0.1441	0.1459	0.1477	0.1495	0.1512	0.1530	0.1548	0.1566	0.1584	3 6 9 12 15	
9	0.1584	0.1602	0.1620	0.1638	0.1655	0.1673	0.1691	0.1709	0.1727	0.1745	0.1763	3 6 9 12 15	
10°	0.1763	0.1781	0.1799	0.1817	0.1835	0.1853	0.1871	0.1890	0.1908	0.1926	0.1944	3 6 9 12 15	
11	0.1944	0.1962	0.1980	0.1998	0.2016	0.2035	0.2053	0.2071	0.2089	0.2107	0.2125	3 6 9 12 15	
12	0.2126	0.2144	0.2162	0.2180	0.2199	0.2217	0.2235	0.2254	0.2272	0.2290	0.2308	3 6 9 12 15	
13	0.2309	0.2327	0.2345	0.2364	0.2382	0.2401	0.2419	0.2438	0.2456	0.2475	0.2493	3 6 9 12 15	
14	0.2493	0.2512	0.2530	0.2549	0.2568	0.2586	0.2605	0.2623	0.2642	0.2661	0.2679	3 6 9 12 15	
15	0.2679	0.2698	0.2717	0.2736	0.2754	0.2773	0.2792	0.2811	0.2830	0.2849	0.2867	3 6 9 12 15	
16	0.2867	0.2886	0.2905	0.2924	0.2943	0.2962	0.2981	0.3000	0.3019	0.3038	0.3057	3 6 9 12 15	
17	0.3057	0.3076	0.3096	0.3115	0.3134	0.3153	0.3172	0.3191	0.3211	0.3230	0.3249	3 6 9 12 15	
18	0.3249	0.3269	0.3288	0.3307	0.3327	0.3346	0.3365	0.3385	0.3404	0.3424	0.3443	3 6 9 12 15	
19	0.3443	0.3463	0.3482	0.3502	0.3522	0.3541	0.3561	0.3581	0.3600	0.3620	0.3640	3 6 9 12 15	
20°	0.3640	0.3659	0.3679	0.3699	0.3719	0.3739	0.3759	0.3779	0.3799	0.3819	0.3839	3 6 9 12 15	
21	0.3839	0.3859	0.3879	0.3899	0.3919	0.3939	0.3959	0.3979	0.4000	0.4020	0.4040	3 6 9 12 15	
22	0.4040	0.4061	0.4081	0.4101	0.4122	0.4142	0.4163	0.4183	0.4204	0.4224	0.4245	3 6 9 12 15	
23	0.4245	0.4265	0.4286	0.4307	0.4327	0.4348	0.4369	0.4390	0.4411	0.4431	0.4452	3 6 9 12 15	
24	0.4452	0.4473	0.4494	0.4515	0.4536	0.4557	0.4578	0.4599	0.4621	0.4642	0.4663	3 6 9 12 15	
25	0.4663	0.4684	0.4706	0.4727	0.4748	0.4770	0.4791	0.4813	0.4834	0.4856	0.4877	3 6 9 12 15	
26	0.4877	0.4899	0.4921	0.4942	0.4964	0.4986	0.5008	0.5029	0.5051	0.5073	0.5095	3 6 9 12 15	
27	0.5095	0.5117	0.5139	0.5161	0.5184	0.5206	0.5228	0.5250	0.5272	0.5295	0.5317	3 6 9 12 15	
28	0.5317	0.5340	0.5362	0.5384	0.5407	0.5430	0.5452	0.5475	0.5498	0.5520	0.5543	3 6 9 12 15	
29	0.5543	0.5566	0.5589	0.5612	0.5635	0.5658	0.5681	0.5704	0.5727	0.5750	0.5774	3 6 9 12 15	
30°	0.5774	0.5797	0.5820	0.5844	0.5867	0.5890	0.5914	0.5938	0.5961	0.5985	0.6009	3 6 9 12 15	
31	0.6009	0.6032	0.6056	0.6080	0.6104	0.6128	0.6152	0.6176	0.6200	0.6224	0.6248	3 6 9 12 15	
32	0.6249	0.6273	0.6297	0.6322	0.6346	0.6371	0.6395	0.6420	0.6445	0.6469	0.6494	3 6 9 12 15	
33	0.6494	0.6519	0.6544	0.6569	0.6594	0.6619	0.6644	0.6669	0.6694	0.6720	0.6745	3 6 9 12 15	
34	0.6745	0.6771	0.6796	0.6822	0.6847	0.6873	0.6899	0.6924	0.6950	0.6976	0.7002	3 6 9 12 15	
35	0.7002	0.7028	0.7054	0.7080	0.7107	0.7133	0.7159	0.7186	0.7212	0.7239	0.7265	3 6 9 12 15	
36	0.7265	0.7292	0.7319	0.7346	0.7373	0.7400	0.7427	0.7454	0.7481	0.7508	0.7535	3 6 9 12 15	
37	0.7535	0.7563	0.7590	0.7618	0.7646	0.7673	0.7701	0.7729	0.7757	0.7785	0.7812	3 6 9 12 15	
38	0.7813	0.7841	0.7869	0.7898	0.7926	0.7954	0.7983	0.8012	0.8040	0.8069	0.8098	3 6 9 12 15	
39	0.8098	0.8127	0.8156	0.8185	0.8214	0.8243	0.8273	0.8302	0.8332	0.8361	0.8391	3 6 9 12 15	
40°	0.8391	0.8421	0.8451	0.8481	0.8511	0.8541	0.8571	0.8601	0.8632	0.8662	0.8691	3 6 9 12 15	
41	0.8693	0.8724	0.8754	0.8785	0.8816	0.8847	0.8878	0.8910	0.8941	0.8972	0.9004	3 6 9 12 15	
42	0.9004	0.9036	0.9067	0.9099	0.9131	0.9163	0.9195	0.9228	0.9260	0.9293	0.9325	3 6 9 12 15	
43	0.9325	0.9358	0.9391	0.9424	0.9457	0.9490	0.9523	0.9556	0.9590	0.9623	0.9657	3 6 9 12 15	
44	0.9657	0.9691	0.9725	0.9759	0.9793	0.9827	0.9861	0.9896	0.9930	0.9965	0.9999	3 6 9 12 15	

Natural Cotangents:

$\text{Cot } x^\circ = \tan(90 - x)^\circ$ and use above table.

Natural Tangents

11

	0°	Mean Differences											
		0' 0°	6' 0' 1°	12' 0' 2°	18' 0' 3°	24' 0' 4°	30' 0' 5°	36' 0' 6°	42' 0' 7°	48' 0' 8°	54' 0' 9°	1' 2' 3' 4' 5'	
	45°	1.0000	0.035	0.070	0.105	0.141	0.176	0.212	0.247	0.283	0.319	6 12 18 24 30	
46	1.0355	0.092	0.148	0.194	0.241	0.287	0.334	0.381	0.427	0.474	0.521	6 12 18 25 31	
47	1.0724	0.0761	0.109	0.143	0.177	0.213	0.247	0.281	0.313	0.347	0.381	6 13 19 25 32	
48	1.1106	1.145	1.184	1.224	1.263	1.303	1.343	1.383	1.423	1.463	1.503	7 13 20 27 33	
49	1.1504	1.154	1.185	1.226	1.267	1.308	1.348	1.389	1.429	1.469	1.509	7 14 21 28 34	
50°	1.1918	1.196	1.202	1.245	1.288	1.321	1.374	1.421	1.464	1.507	1.547	7 14 22 29 36	
51	1.2349	1.239	1.247	1.284	1.321	1.358	1.405	1.452	1.499	1.546	1.583	8 15 23 30 38	
52	1.2799	1.284	1.293	1.329	1.366	1.403	1.440	1.487	1.534	1.581	1.628	8 16 24 31 39	
53	1.3270	1.331	1.337	1.374	1.411	1.448	1.485	1.532	1.569	1.606	1.643	8 16 25 33 41	
54	1.3764	1.384	1.386	1.416	1.443	1.479	1.516	1.553	1.589	1.626	1.663	8 17 26 34 43	
55	1.4281	1.435	1.438	1.474	1.501	1.538	1.575	1.612	1.649	1.686	1.723	8 18 27 36 45	
56	1.4826	1.488	1.493	1.520	1.547	1.574	1.611	1.648	1.685	1.722	1.759	8 19 29 38 48	
57	1.5399	1.548	1.557	1.584	1.611	1.639	1.666	1.703	1.730	1.767	1.804	10 20 30 40 50	
58	1.6003	1.608	1.628	1.655	1.682	1.710	1.737	1.764	1.791	1.818	1.845	11 21 32 43 53	
59	1.6643	1.679	1.684	1.711	1.738	1.765	1.792	1.819	1.846	1.873	1.900	11 22 34 45 56	
60°	1.7321	1.739	1.746	1.782	1.809	1.836	1.863	1.890	1.917	1.944	1.971	12 24 36 48 60	
61	1.8040	1.815	1.819	1.856	1.884	1.911	1.938	1.965	1.992	2.019	2.046	13 26 38 51 64	
62	1.8807	1.887	1.897	1.924	1.951	1.978	2.005	2.032	2.059	2.086	2.113	14 27 41 55 68	
63	1.9628	1.971	1.979	2.006	2.033	2.060	2.087	2.114	2.141	2.168	2.195	15 29 44 58 73	
64	2.0503	0.054	0.068	0.078	0.092	0.106	0.120	0.134	0.148	0.162	0.176	16 31 47 63 78	
65	2.1445	1.543	1.642	1.742	1.842	1.943	2.045	2.145	2.245	2.345	2.445	17 34 51 68 85	
66	2.2460	2.266	2.273	2.281	2.289	2.298	2.306	2.314	2.322	2.330	2.338	18 37 55 73 92	
67	2.3559	2.3673	2.379	2.390	2.403	2.414	2.426	2.438	2.450	2.462	2.474	20 40 60 79 99	
68	2.4751	2.4870	2.502	2.519	2.537	2.555	2.573	2.591	2.609	2.627	2.645	22 43 65 87 108	
69	2.6051	2.6187	2.635	2.652	2.670	2.688	2.706	2.724	2.742	2.760	2.778	24 47 71 95 119	
70°	2.7475	2.7625	2.776	2.792	2.808	2.824	2.839	2.855	2.871	2.888	2.905	26 52 78 104 131	
71	2.9042	2.9208	2.935	2.951	2.967	2.983	2.999	3.015	3.031	3.047	3.063	29 58 87 116 145	
72	3.0777	0.061	1.146	1.334	1.524	1.716	1.910	2.106	2.305	2.506	2.704	32 64 98 129 161	
73	3.2709	2.914	3.122	3.332	3.544	3.759							

Natural Secants

12

	Mean Differences											
	0°	8'	12'	18'	24'	30'	36'	42'	48'	54'	1' 2'	3' 4' 5'
0°	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0 0 0	0 0 0	
1	1.0002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.005	0.006	0 0 0	0 0 0
2	1.0006	0.007	0.007	0.008	0.009	0.010	0.010	0.011	0.012	0.013	0 0 0	1 1
3	1.0014	0.015	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0 0 1	1 1
4	1.0024	0.026	0.027	0.028	0.030	0.031	0.032	0.034	0.035	0.037	0 0 1	1 1
5	1.0038	0.040	0.041	0.043	0.045	0.046	0.048	0.050	0.051	0.053	0 1 1	1 2
6	1.0055	0.057	0.059	0.061	0.063	0.065	0.067	0.069	0.071	0.073	0 1 1	1 2
7	1.0075	0.077	0.079	0.082	0.084	0.086	0.089	0.091	0.093	0.096	0 1 1	2 2
8	1.0098	0.101	0.103	0.106	0.108	0.111	0.114	0.116	0.119	0.122	0 1 1	2 2
9	1.0125	0.127	0.130	0.133	0.136	0.139	0.142	0.145	0.148	0.151	0 1 1	2 2
10	1.0154	0.157	0.161	0.164	0.167	0.170	0.174	0.177	0.180	0.184	1 1 2	2 3
11	1.0187	0.191	0.194	0.198	0.201	0.205	0.209	0.212	0.216	0.220	1 1 2	2 3
12	1.0223	0.227	0.231	0.235	0.239	0.243	0.247	0.251	0.255	0.259	1 1 2	3 3
13	1.0263	0.267	0.271	0.276	0.280	0.284	0.288	0.293	0.297	0.302	1 1 2	3 4
14	1.0306	0.311	0.315	0.320	0.324	0.329	0.334	0.338	0.343	0.348	1 2 2	3 4
15	1.0353	0.358	0.363	0.367	0.372	0.377	0.382	0.386	0.393	0.398	1 2 3	3 4
16	1.0403	0.408	0.413	0.419	0.424	0.429	0.435	0.440	0.446	0.451	1 2 3	4 4
17	1.0457	0.463	0.468	0.474	0.480	0.485	0.491	0.497	0.503	0.509	1 2 3	4 5
18	1.0515	0.521	0.527	0.533	0.539	0.545	0.551	0.557	0.564	0.570	1 2 3	4 5
19	1.0576	0.583	0.589	0.595	0.602	0.608	0.615	0.622	0.628	0.635	1 2 3	4 5
20	1.0642	0.649	0.655	0.662	0.669	0.676	0.683	0.690	0.697	0.704	1 2 3	5 6
21	1.0711	0.719	0.726	0.733	0.740	0.748	0.755	0.763	0.770	0.778	1 2 4	5 6
22	1.0785	0.793	0.801	0.808	0.816	0.824	0.832	0.840	0.848	0.856	1 3 4	5 7
23	1.0864	0.872	0.880	0.888	0.896	0.904	0.913	0.921	0.929	0.938	1 3 4	5 7
24	1.0946	0.955	0.963	0.972	0.981	0.989	0.998	1.007	1.015	1.025	1 3 4	6 7
25	1.1034	1.043	1.052	1.061	1.070	1.079	1.089	1.098	1.107	1.117	2 3 5	6 8
26	1.1126	1.136	1.145	1.155	1.164	1.174	1.184	1.194	1.203	1.213	2 3 5	6 8
27	1.1223	1.233	1.243	1.253	1.264	1.274	1.284	1.294	1.305	1.315	2 3 5	7 9
28	1.1326	1.336	1.347	1.357	1.368	1.379	1.390	1.401	1.412	1.423	2 4 5	7 9
29	1.1434	1.445	1.456	1.467	1.478	1.490	1.501	1.512	1.524	1.535	2 4 6	8 9
30	1.1547	1.559	1.570	1.582	1.594	1.606	1.618	1.630	1.642	1.654	2 4 6	8 10
31	1.1666	1.679	1.691	1.703	1.716	1.728	1.741	1.753	1.766	1.779	2 4 6	8 10
32	1.1792	1.805	1.818	1.831	1.844	1.857	1.870	1.883	1.897	1.910	2 4 7	9 11
33	1.1924	1.937	1.951	1.964	1.978	1.992	2.006	2.020	2.034	2.048	2 5 7	9 11
34	1.2062	2.076	2.091	2.105	2.120	2.134	2.149	2.163	2.178	2.193	2 5 7	10 12
35	1.2208	2.223	2.238	2.253	2.268	2.283	2.299	2.314	2.329	2.345	3 5 8	10 13
36	1.2361	2.376	2.392	2.408	2.424	2.440	2.456	2.472	2.488	2.505	2 5 8	11 13
37	1.2521	2.538	2.554	2.571	2.588	2.605	2.622	2.639	2.658	2.673	3 6 8	11 14
38	1.2690	2.708	2.725	2.742	2.760	2.778	2.796	2.813	2.831	2.849	3 6 9	12 15
39	1.2868	2.886	2.904	2.923	2.941	2.960	2.978	2.997	3.016	3.035	3 6 9	12 15
40	1.3054	3.073	3.093	3.112	3.131	3.151	3.171	3.190	3.210	3.230	3 7 10	13 16
41	1.3250	3.270	3.291	3.311	3.331	3.352	3.373	3.393	3.414	3.435	3 7 10	14 17
42	1.3456	3.478	3.499	3.520	3.542	3.563	3.585	3.607	3.629	3.651	4 7 11	14 18
43	1.3673	3.696	3.718	3.741	3.763	3.786	3.809	3.832	3.855	3.878	4 8 11	15 19
44	1.3902	3.925	3.949	3.972	3.996	4.020	4.044	4.069	4.093	4.118	4 8 12	16 20

Natural Cosecants:

Cosec $x^\circ = \sec(90-x)^\circ$ and use above table.

Natural Secants

13

	Mean Differences											
	0°	8'	12'	18'	24'	30'	36'	42'	48'	54'	1' 2'	3' 4' 5'
45°	1.4142	4167	4192	4217	4242	4267	4293	4318	4344	4370	4 8 13	17 21
46	1.4396	4422	4448	4474	4501	4527	4554	4581	4608	4635	4 9 13	18 22
47	1.4663	4690	4718	4746	4774	4802	4830	4859	4887	4916	5 9 14	19 23
48	1.4945	4974	5003	5032	5062	5092	5121	5151	5182	5212	5 10 15	20 25
49	1.5243	5273	5304	5335	5366	5398	5429	5461	5493	5525	5 10 16	21 26
50°	1.5557	5590	5622	5655	5688	5721	5755	5788	5822	5856	6 11 17	22 28
51	1.5890	5925	5959	5994	6029	6064	6099	6135	6171	6207	6 12 18	24 29
52	1.6243	6279	6316	6353	6390	6427	6464	6502	6540	6578	6 12 19	25 31
53	1.6616	6655	6694	6733	6772	6812	6852	6892	6932	6972	7 13 20	26 33
54	1.7013	7054	7095	7137	7179	7221	7263	7305	7348	7391	7 14 21	28 35
55	1.7434	7478	7522	7566	7610	7655	7700	7745	7791	7837	7 15 22	30 37
56	1.7883	7929	7976	8023	8070	8118	8166	8214	8263	8312	8 16 24	32 40
57	1.8361	8410	8460	8510	8561	8612	8663	8714	8766	8818	8 17 25	34 42
58	1.8871	8924	8977	9031	9084	9139	9194	9249	9304	9360	9 18 27	36 45
59	1.9416	9473	9530	9587	9645	9703	9762	9821	9880	9940	10 19 29	39 49
60°	2.0000	0.061	0.122	0.183	0.245	0.308	0.371	0.434	0.498	0.562		
61	2.0627	0.692	0.757	0.824	0.890	0.957	1.023	1.093	1.162	1.231	11 22 34	45 56
62	2.1301	1.371	1.441	1.513	1.584	1.657	1.730	1.803	1.877	1.952	11 24 36	48 60
63	2.2027	2.103	2.179	2.258	2.333	2.412	2.490	2.570	2.650	2.730	13 26 39	52 65
64	2.2812	2.894	2.976	3.060	3.144	3.228	3.314	3.400	3.486	3.574	14 28 42	57 71
65	2.3662	3.751	3.841	3.931	4.022	4.114	4.207	4.300	4.395	4.490	15 31 46	62 77
66	2.4586	4683	4780	4879	4978	5078	5180	5282	5384	5488		
67	2.5593	5699	5805	5913	6022	6131	6242	6354	6468	6580		
68	2.6695	6811	6927	7046	7165	7285	7407	7529	7653	7778		
69	2.7904	8032	8161	8291	8422	8555	8688	8824	8960	9099		
70°	2.9238	9379	9521	9665	9811	9957	1018	1040	1076	1104		
71	3.0716	1082	1030	1190	1352	1515	1681	1848	2017	2188		
72	3.3261	2535	2712	2891	3072	3255	3440	3628	3817	4009		
73	3.4203	4399	4598	4799	5003	5209	5418	5629	5843	6060		
74	3.6280	6502	6727	6955	7186	7420	7657	7897	8140	8387		
75	3.8637	8890	9147	9408	9872	9939	10211	10488	10765	1048		
76	4.1336	1827	1923	2223	2527	2837	3150	3469	3792	4121		
77	4.4454	4793	5137	5486	5841	6205	6589	6942	7321	7708		
78	4.8097	8496	8901	9313	9732	10199	10593	10934	1484	1942		
79	5.2408	2883	3367	3860	4362	4874	5396	5928	6470	7023		
80°	5.7588	8164	8751	9351	9933	0589	1227	1880	2546	3228		
81	6.3925	4637	5366	6111	6874	7855	8454	9273	1012	1072		
82	7.1853	2757	3684	4633	5611	6613	7642	8700	9787	10905		
83	8.2055	3238	4457	5711	7004	8337	9711	1129	2593	4105		
84	9.5688	7283	8955	0685	2477	4334	8261	8260	0336	2493		
85	11.474	11.71	11.95	12.20	12.47	13.03	13.34	13.65	13.99			
86	14.34	14.70	15.09	15.50	15.93	16.38	16.86	17.37</td				

Logarithmic Sines

14

	0°	Mean Differences													
		0' 0°	6' 0·1°	12' 0·2°	18' 0·3°	24' 0·4°	30' 0·5°	36' 0·6°	42' 0·7°	48' 0·8°	54' 0·9°	1' 1°	2' 2°	3' 3°	4' 4°
0°	—∞	3·2419	5429	7190	8439	9408	0200	0870	1450	1961					
1	2·2419	2832	3210	3558	3880	4179	4459	4723	4971	5206					
2	2·5428	5640	5842	6035	6220	6397	6567	6731	6889	7041					
3	2·7188	7330	7468	7602	7731	7857	7979	8098	8213	8326					
4	2·8436	8543	8647	8749	8849	8946	9042	9135	9226	9315	16 32 48	64 80			
5	2·9403	9489	9573	9555	9736	9818	9894	9970	0046	0120	13 26 39	52 65			
6	T-0192	0264	0334	0403	0472	0539	0605	0670	0734	0797	11 22 33	44 55			
7	T-0859	0920	0981	1040	1099	1157	1214	1271	1326	1381	10 19 29	38 48			
8	T-1438	1489	1542	1594	1648	1697	1747	1797	1847	1895	8 17 25	34 42			
9	T-1943	1991	2038	2085	2131	2176	2221	2266	2310	2353	8 15 23	30 38			
10°	T-2397	2439	2482	2524	2565	2606	2647	2687	2727	2767	7 14 20	27 34			
11	T-2806	2845	2883	2921	2959	2997	3034	3070	3107	3143	6 12 19	25 31			
12	T-3179	3214	3250	3284	3319	3353	3387	3421	3455	3488	6 11 17	23 28			
13	T-3521	3554	3586	3618	3650	3682	3713	3745	3775	3806	5 11 16	21 26			
14	T-3837	3867	3897	3927	3957	3986	4015	4044	4073	4102	5 10 15	20 24			
15	T-4130	4158	4186	4214	4242	4269	4296	4323	4350	4377	5 9 14	18 23			
16	T-4403	4430	4456	4482	4508	4533	4559	4584	4609	4634	4 9 13	17 21			
17	T-4459	4684	4709	4733	4757	4781	4805	4829	4853	4876	4 8 12	16 20			
18	T-4900	4923	4948	4969	4992	5015	5037	5060	5082	5104	4 8 11	15 19			
19	T-5126	5148	5170	5192	5213	5235	5256	5278	5299	5320	4 7 11	14 18			
20°	T-5341	5361	5382	5402	5423	5443	5463	5484	5504	5523	3 7 10	14 17			
21	T-5543	5563	5583	5602	5621	5641	5660	5679	5698	5717	3 6 10	13 16			
22	T-5736	5754	5773	5792	5810	5828	5847	5865	5883	5901	3 6 9	12 15			
23	T-5919	5937	5954	5972	5990	6007	6024	6042	6059	6076	3 6 9	12 15			
24	T-6093	6110	6127	6144	6161	6177	6194	6210	6227	6243	3 6 8	11 14			
25	T-6259	6276	6292	6308	6324	6340	6356	6371	6387	6403	3 5 8	11 13			
26	T-6418	6434	6449	6465	6480	6495	6510	6526	6541	6556	3 5 8	10 13			
27	T-6570	6585	6600	6615	6629	6644	6659	6673	6687	6702	2 5 7	10 12			
28	T-6716	6730	6744	6759	6773	6787	6801	6814	6828	6842	2 5 7	9 12			
29	T-6858	6869	6883	6896	6910	6923	6937	6950	6963	6977	2 4 7	9 11			
30°	T-6990	7003	7016	7029	7042	7055	7068	7080	7093	7106	2 4 6	9 11			
31	T-7118	7131	7144	7156	7168	7181	7193	7205	7218	7230	2 4 6	8 10			
32	T-7242	7254	7266	7278	7290	7302	7314	7326	7338	7349	2 4 6	8 10			
33	T-7361	7373	7384	7396	7407	7419	7430	7442	7453	7464	2 4 6	8 10			
34	T-7476	7487	7498	7509	7520	7531	7542	7553	7564	7575	2 4 6	7 9			
35	T-7586	7597	7607	7618	7629	7640	7650	7661	7671	7682	2 4 5	7 9			
36	T-7692	7703	7713	7723	7734	7744	7754	7764	7774	7785	2 3 5	7 9			
37	T-7795	7805	7815	7825	7835	7844	7854	7864	7874	7884	2 3 5	7 8			
38	T-7893	7903	7913	7922	7932	7941	7951	7960	7970	7979	2 3 5	6 8			
39	T-7989	7998	8007	8017	8026	8035	8044	8053	8063	8072	2 3 5	6 8			
40°	T-8081	8090	8099	8108	8117	8125	8134	8143	8152	8161	1 3 4	6 7			
41	T-8189	8178	8187	8195	8204	8213	8221	8230	8238	8247	1 3 4	6 7			
42	T-8255	8264	8272	8280	8289	8297	8305	8313	8322	8330	1 3 4	6 7			
43	T-8338	8346	8354	8362	8370	8378	8386	8394	8402	8410	1 3 4	5 7			
44	T-8418	8426	8433	8441	8449	8457	8464	8472	8480	8487	1 3 4	5 6			

Logarithmic Sines

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	45°	Mean Differences														
		0' 0°	6' 0·1°	12' 0·2°	18' 0·3°	24' 0·4°	30' 0·5°	36' 0·6°	42' 0·7°	48' 0·8°	54' 0·9°	1' 1°	2' 2°	3' 3°	4' 4°	5' 5°
	T-8495	8502	8510	8517	8525	8532	8540	8547	8555	8562		1	2	4	5	6
46	T-8569	8577	8584	8591	8598	8606	8613	8620	8627	8634		1	2	4	5	6
47	T-8641	8648	8655	8662	8669	8676	8683	8690	8697	8704		1	2	3	5	6
48	T-8711	8718	8724	8731	8738	8745	8751	8758	8765	8771		1	2	3	4	5
49	T-8778	8784	8791	8797	8804	8810	8817	8823	8830	8838		1	2	3	4	5
50°	T-8843	8849	8855	8862	8868	8874	8880	8887	8893	8899		1	2	3	4	5
51	T-8905	8911	8917	8923	8929	8935	8941	8947	8953	8959		1	2	3	4	5
52	T-8965	8971	8977	8983	8989	8995	9000	9008	9012	9018		1	2	3	4	5
53	T-9023	9029	9035	9041	9048	9052	9057	9063	9069	9074		1	2	3	4	5
54	T-9080	9085	9091	9096	9101	9107	9112	9118	9123	9128		1	2	3	4	5
55	T-9134	9139	9144	9149	9155	9160	9165	9170	9175	9181		1	2	3	4	5
56	T-9188	9191	9196	9201	9206	9211	9216	9221	9226	9231		1	2	3	4	5
57	T-9236	9241	9246	9251	9255	9260	9265	9270	9275	9279		1	2	3	4	5
58	T-9284	9289	9294	9298	9303	9308	9312	9317	9322	9326		1	2	3	4	5
59	T-9331	9335	9340	9344	9349	9353	9358	9362	9367	9371		1	2	3	4	5
60°	T-9375	9380	9384	9388	9393	9397	9401	9408	9414	9418		1	2	3	4	5
61	T-9442	9447	9452	9451	9453	9459	9464	9467	9471	9475		1	2	3	4	5
62	T-9450	9453	9467	9471	9475	9479	9483	9487	9491	9495		1	2	3	4	5
63	T-9499	9503	9507	9510	9514	9518	9522	9525	9529	9533		1	2	3	4	5
64	T-9537	9540	9544	9548	9551	9555	9558	9562	9566	9569		1	2	3	4	5
65	T-9573	9576	9581	9585	9590	9595	9601	9606	9610	9614		1	2	3	4	5
66	T-9607	9611	9614	9617	9621	9624	9627	9631	9634	9637		1	2	3	4	5
67	T-9640	9643	9647	9650	9653	9656	9659	9662	9666	9669		1	2	3	4	5
68	T-9672	9675	9678	9681	9684	9687	9690	9693	9696	9699		0	1	2	3	4
69	T-9702	9704	9707	9710	9713	9716	9719	9722	9724	9727		0	1	1	2	3
70°	T-9730	9733	9735	9738	9741	9743	9746	9749	9751	9754		0	1	1	2	3
71	T-9757	9759	9762	9764	9767	9770	9772	9775	9777	9780		0	1	1	2	3
72	T-9782	9785	9787	9789	9792	9794	9797	9799	9801	9804		0	1	1	2	3
73	T-9806	9808	9811	9813	9815	9817	9820	9822	9824	9826		0	1	1	2	3
74	T-9828	9831	9833	9835	9837	9839	9841	9843	9845	9847		0	1	1	1	2
75	T-9849	9851	9855	9857	9859	9861	9863	9865	9867	9869		0	1	1	1	2
76	T-9887	9873	9875	9876	9878	9880	9882	9884	9886	9888		0	1	1	1	2
77	T-9889	9891	9892	9894	9896	9897	9899	9901	9902	9904		0	1	1	1	2
78	T-9904	9906	9907	9909	9910	9912	9913	9915	9916	9918		0	1	1	1	2
79	T-9919	9921	9922	9924	9925	9927	9928	9929	9							

Logarithmic Cosines

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	0°	SUBTRACT Mean Differences													
		0' 0°	6' 0°	12' 0°	18' 0°	24' 0°	30' 0°	36' 0°	42' 0°	48' 0°	54' 0°	1' 1°	2' 1°	3' 1°	4' 1°
0°	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0	0
1°	T-9999	9999	9999	9999	9999	9999	9998	9998	9998	9998	9998	0	0	0	0
2°	T-9997	9997	9997	9996	9996	9996	9995	9995	9995	9994	9994	0	0	0	0
3°	T-9994	9994	9993	9993	9992	9992	9991	9990	9990	9990	9990	0	0	0	0
4°	T-9989	9989	9988	9988	9987	9987	9986	9985	9985	9984	9984	0	0	0	0
5°	T-9983	9983	9982	9981	9981	9980	9979	9978	9978	9977	9977	0	0	0	1
6°	T-9976	9975	9975	9974	9973	9972	9971	9970	9969	9968	9968	0	0	0	1
7°	T-9968	9968	9968	9965	9964	9963	9962	9961	9960	9959	9959	0	0	1	1
8°	T-9956	9956	9955	9954	9953	9952	9951	9950	9949	9947	9947	0	0	1	1
9°	T-9946	9945	9944	9943	9941	9940	9939	9937	9936	9935	9935	0	0	1	1
10°	T-9934	9932	9931	9929	9928	9927	9925	9924	9922	9921	9921	0	0	1	1
11°	T-9919	9918	9916	9915	9913	9912	9910	9909	9907	9906	9906	0	1	1	1
12°	T-9904	9902	9901	9899	9897	9896	9894	9892	9891	9889	9889	0	1	1	1
13°	T-9887	9885	9884	9882	9880	9878	9876	9875	9873	9871	9871	0	1	1	2
14°	T-9869	9867	9865	9863	9861	9859	9857	9855	9853	9851	9851	0	1	1	2
15°	T-9849	9847	9845	9843	9839	9837	9835	9833	9831	9831	9831	0	1	1	2
16°	T-9828	9826	9824	9822	9820	9817	9815	9813	9811	9808	9808	0	1	1	2
17°	T-9806	9804	9801	9799	9797	9794	9792	9789	9787	9785	9785	0	1	1	2
18°	T-9782	9780	9777	9775	9772	9770	9767	9764	9762	9759	9759	0	1	1	2
19°	T-9757	9754	9751	9749	9746	9743	9741	9738	9735	9733	9733	0	1	1	2
20°	T-9730	9727	9724	9722	9719	9718	9713	9710	9707	9704	9704	0	1	1	2
21°	T-9702	9699	9698	9693	9690	9687	9684	9681	9678	9675	9675	0	1	1	2
22°	T-9672	9669	9668	9662	9659	9656	9653	9650	9647	9643	9643	1	1	2	3
23°	T-9640	9637	9634	9631	9627	9624	9621	9617	9614	9611	9611	1	1	2	3
24°	T-9607	9604	9601	9597	9594	9590	9587	9583	9580	9576	9576	1	1	2	3
25°	T-9573	9569	9566	9562	9558	9555	9551	9548	9544	9540	9540	1	1	2	3
26°	T-9537	9533	9529	9525	9522	9518	9514	9510	9507	9503	9503	1	1	2	3
27°	T-9499	9495	9491	9487	9483	9479	9475	9471	9467	9463	9463	1	1	2	3
28°	T-9459	9455	9451	9447	9443	9439	9435	9431	9427	9422	9422	1	1	2	3
29°	T-9418	9414	9410	9406	9401	9397	9393	9388	9384	9380	9380	1	1	2	3
30°	T-9375	9371	9367	9362	9358	9353	9349	9344	9340	9335	9335	1	1	2	3
31°	T-9331	9326	9322	9317	9312	9308	9303	9298	9294	9289	9289	1	2	2	3
32°	T-9294	9279	9275	9270	9265	9260	9255	9251	9246	9241	9241	1	2	2	3
33°	T-9236	9231	9226	9221	9218	9211	9206	9201	9198	9191	9191	1	2	3	3
34°	T-9186	9181	9175	9170	9165	9160	9155	9149	9144	9139	9139	1	2	3	3
35°	T-9134	9128	9123	9118	9112	9107	9101	9098	9091	9085	9085	1	2	3	5
36°	T-9080	9074	9069	9063	9057	9052	9046	9041	9035	9029	9029	1	2	3	5
37°	T-9023	9018	9012	9008	9000	8995	8989	8983	8977	8971	8971	1	2	3	5
38°	T-8985	8959	8953	8947	8941	8935	8929	8923	8917	8911	8911	1	2	3	5
39°	T-8905	8899	8893	8887	8880	8874	8868	8862	8855	8849	8849	1	2	3	5
40°	T-8843	8836	8830	8823	8817	8810	8804	8797	8791	8784	8784	1	2	3	5
41°	T-8778	8771	8765	8768	8751	8745	8738	8731	8724	8718	8718	1	2	3	5
42°	T-8711	8704	8697	8689	8683	8678	8669	8662	8655	8648	8648	1	2	3	5
43°	T-8641	8634	8627	8620	8613	8606	8598	8591	8584	8577	8577	1	2	3	5
44°	T-8589	8562	8555	8547	8540	8532	8525	8517	8510	8502	8502	1	2	4	5

Logarithmic Cosines

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	0°	SUBTRACT Mean Differences													
		0' 0°	6' 0°	12' 0°	18' 0°	24' 0°	30' 0°	36' 0°	42' 0°	48' 0°	54' 0°	1' 1°	2' 1°	3' 1°	4' 1°
45°	T-8495	8487	8480	8472	8464	8457	8449	8441	8433	8426	8426	1	3	4	5
46°	T-8418	8410	8402	8394	8386	8378	8370	8362	8354	8346	8346	1	3	4	5
47°	T-8338	8330	8322	8313	8305	8297	8289	8280	8272	8264	8264	1	3	4	5
48°	T-8255	8247	8238	8230	8221	8213	8204	8195	8187	8178	8178	1	3	4	5
49°	T-8169	8161	8152	8143	8134	8125	8117	8103	8099	8090	8090	2	3	5	6
50°	T-8081	8073	8063	8053	8044	8035	8026	8017	8007	7998	7998	2	3	5	6
51°	T-7999	7979	7970	7960	7951	7941	7932	7922	7913	7903	7903	2	3	5	6
52°	T-7903	7894	7874	7854	7834	7815	7805	7796	7787	7778	7778	2	3	5	7
53°	T-7795	7765	7774	7764	7754	7744	7734	7723	7713	7703	7703	2	4	5	7
54°	T-7692	7682	7671	7661	7650	7640	7629	7618	7607	7597	7597	2	4	5	7
55°	T-7585	7575	7553	7542	7531	7520	7509	7498	7487	7477	7477	2	4	5	7
56°	T-7476	7454	7442	7430	7419	7407	7398	7384	7373	7363	7363	2	4	6	8
57°	T-7381	7349	7330	7320	7314	7302	7290	7286	7274	7264	7264	2	4	6	8
58°	T-7242	7230	7216	7205	7193	7181	7168	7159	7144	7131	7131	2	4	6	8
59°	T-7113	7083	7080	7068	7055	7042	7029	7016	7003	6991	6991	2	4	6	8
60°	T-6990	6977	6963	6950	6931	6915	6900	6886	6873	6863	6863	2	4	7	9
61°	T-6856	6842	6828	6814	6801	6787	6773	6759	6744	6730	6730	2	4	7	12
62°	T-6716	6702	6687	6673	6659	6644	6629	6615	6600	6585	6585	2	4	7	12
63°	T-6570	6556	6541	6526	6510	6495	6480	6465	6449	6434	6434	2	4	8	13
64°	T-6418	6403	6387	6371	6356	6341	6324	6308	6292	6276	6276	2	4	8	13
65°	T-6259	6243	6227	6210	6194	6177	6161	6144	6127	6110	6110	2	4	8	14
66°	T-6093	6076	6059	6042	6024	6007	5980	5972	5954	5937	5937	2	4	9	15
67°	T-5919	5891	5853	5835	5817	5792	5773	5754	5735	5716	5716	2	4	9	15
68°	T-5738	5717	5698	5679	5660	5641	5621	5602	5583	5563	5563	2	4	10	16
69°	T-5543	5523	5504	5484	5463	5443	5423	5402	5382	5361	5361	2	4	10	17
70°	T-5341	5290	5278	5258	5235	5213	5192	5170	5148	5127	5127	2	4	11	18
71°	T-5126	5104	5082	5060	5037	5015	4992	4989	4966	4943	4943	2	4	11	19
72°	T-4900	4876	4853	4829	4805	4781	4757	4733	4709	4684	4684	2	4	12	20
73°	T-4659	4634	4609	4584	4559	4533	4508	4482	4456	4430	4430	2	4	13	21
74°	T-4403	4377	4350	4323	4296	4269	4242	4214	4186	4158	4158	2	4	14	22
75°	T-4130	4102	4073	4044	4015	3986	3957	3927	3897	3867	3867	2	4	15	24
76°	T-3837	3806	3775	3745	3713	3682	3650	3618	3588	3554	3554	2	4	16	25
77°	T-3521	3488	3455	3421	3387	3353	3319	3284	3250	3214	3214	2	4	17	26
78°	T-3179	3143	3107	3070	3034	2997	2959	2921	2883	2845	2845	2	4	18	27
79°															

Logarithmic Tangents

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	0°	Mean Differences													
		0' 0°	6' 0·1°	12' 0·2°	18' 0·3°	24' 0·4°	30' 0·5°	36' 0·6°	42' 0·7°	48' 0·8°	54' 0·9°	1' 0' 0°	2' 0' 0°	3' 0' 0°	4' 0' 0°
	-∞	3.2419	5429	7190	8439	9409	5200	0870	1450	1962					
1°	2.2419	2833	3211	3559	3881	4181	4481	4725	4973	5208					
2°	2.5431	5643	5845	6038	6223	6401	6571	6736	6894	7046					
3°	2.7194	7337	7475	7609	7739	7885	7988	8107	8223	8336					
4°	2.8446	8554	8659	8762	8862	8980	9056	9150	9241	9331	16 32 48	64 81			
5°	2.9420	9506	9591	9674	9756	9838	9915	9992	0068	0143	13 26 40	53 66			
6°	3.0218	0289	0360	0430	0499	0567	0633	0699	0764	0828	11 22 34	45 56			
7°	3.0891	0954	1015	1076	1135	1194	1252	1310	1367	1423	10 20 29	39 49			
8°	3.1478	1533	1587	1640	1693	1745	1797	1848	1898	1948	9 17 26	35 43			
9°	3.1997	2048	2094	2142	2189	2236	2282	2328	2374	2419	8 16 23	31 39			
10°	3.2463	2507	2551	2594	2637	2680	2722	2764	2805	2846	7 14 21	28 35			
11°	3.2887	2927	2967	3006	3046	3085	3123	3162	3200	3237	6 13 19	26 32			
12°	3.3275	3312	3349	3385	3422	3458	3493	3529	3564	3599	6 12 18	24 30			
13°	3.3634	3684	3702	3736	3770	3804	3837	3870	3903	3935	6 11 17	22 28			
14°	3.3968	4000	4032	4064	4095	4127	4158	4189	4220	4250	5 10 16	21 26			
15°	3.4281	4311	4341	4371	4400	4430	4459	4488	4517	4546	5 10 15	20 25			
16°	3.4575	4603	4632	4660	4688	4716	4744	4771	4799	4826	5 9 14	19 23			
17°	3.4853	4880	4907	4934	4961	4987	5014	5040	5066	5092	4 9 13	18 22			
18°	3.5118	5143	5169	5195	5220	5245	5270	5295	5320	5345	4 8 13	17 21			
19°	3.5370	5394	5419	5443	5467	5491	5516	5539	5563	5587	4 8 12	16 20			
20°	3.5611	5634	5658	5681	5704	5727	5750	5773	5796	5819	4 8 12	15 19			
21°	3.5842	5864	5887	5909	5932	5954	5976	5998	6020	6042	4 7 11	15 19			
22°	3.6064	6088	6108	6129	6151	6172	6194	6215	6236	6257	4 7 11	14 18			
23°	3.6279	6300	6321	6341	6362	6383	6404	6424	6445	6465	3 7 10	14 17			
24°	3.6486	6506	6527	6547	6567	6587	6607	6627	6647	6667	3 7 10	13 17			
25°	3.6687	6706	6726	6748	6765	6785	6804	6824	6843	6863	3 7 10	13 16			
26°	3.6882	6901	6920	6939	6958	6977	6996	7015	7034	7053	3 6 9	13 16			
27°	3.7072	7090	7109	7128	7146	7165	7183	7202	7220	7238	3 6 9	12 15			
28°	3.7257	7275	7293	7311	7330	7348	7366	7384	7402	7420	3 6 9	12 15			
29°	3.7438	7455	7473	7491	7509	7526	7544	7562	7579	7597	3 6 9	12 15			
30°	3.7614	7632	7649	7667	7684	7701	7719	7736	7753	7771	3 6 9	12 14			
31°	3.7788	7805	7822	7839	7856	7873	7890	7907	7924	7941	3 6 9	11 14			
32°	3.7958	7875	7992	8008	8025	8042	8059	8075	8092	8109	3 6 8	11 14			
33°	3.8125	8142	8158	8175	8191	8208	8224	8241	8257	8274	3 5 8	11 14			
34°	3.8289	8306	8323	8339	8355	8371	8388	8404	8420	8436	3 5 8	11 14			
35°	3.8452	8468	8484	8501	8517	8533	8549	8565	8581	8597	3 5 8	11 13			
36°	3.8613	8629	8644	8660	8676	8692	8708	8724	8740	8755	3 5 8	11 13			
37°	3.8771	8787	8803	8818	8834	8850	8865	8881	8897	8912	3 5 8	10 13			
38°	3.8928	8944	8958	8975	8990	9006	9022	9037	9053	9068	3 5 8	10 13			
39°	3.9084	9099	9115	9130	9148	9161	9176	9192	9207	9223	3 5 8	10 13			
40°	3.9238	9254	9269	9284	9300	9315	9330	9348	9361	9376	3 5 8	10 13			
41°	3.9392	9407	9422	9438	9453	9468	9483	9499	9514	9529	3 5 8	10 13			
42°	3.9544	9560	9575	9590	9605	9621	9636	9651	9666	9681	3 5 8	10 13			
43°	3.9697	9712	9727	9742	9757	9773	9788	9803	9818	9833	3 5 8	10 13			
44°	3.9848	9864	9879	9894	9909	9924	9939	9955	9970	9985	3 5 8	10 13			

Logarithmic Tangents

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	0°	Mean Differences												
		0' 0°	6' 0·1°	12' 0·2°	18' 0·3°	24' 0·4°	30' 0·5°	36' 0·6°	42' 0·7°	48' 0·8°	54' 0·9°	1' 0' 0°	2' 0' 0°	3' 0' 0°
	45°	0.0000	0015	0030	0045	0061	0076	0091	0106	0121	0136	3 5 8	10 13	
	46°	0.0152	0167	0182	0197	0212	0228	0243	0258	0273	0288	3 5 8	10 13	
	47°	0.0303	0319	0334	0349	0364	0379	0395	0410	0425	0440	3 5 8	10 13	
	48°	0.0456	0471	0486	0501	0517	0533	0547	0562	0578	0593	3 5 8	10 13	
	49°	0.0608	0624	0639	0654	0670	0685	0700	0716	0731	0746	3 5 8	10 13	
	50°	0.0762	0777	0793	0808	0824	0839	0854	0870	0885	0901	3 5 8	10 13	
	51°	0.0916	0932	0947	0963	0978	0994	1010	1025	1041	1058	3 5 8	10 13	
	52°	0.1072	1088	1103	1119	1135	1150	1166	1182	1197	1213	3 5 8	10 13	
	53°	0.1229	1245	1260	1276	1292	1308	1324	1340	1356	1371	3 5 8	11 13	
	54°	0.1387	1403	1419	1435	1451	1467	1483	1499	1516	1532	3 5 8	11 13	
	55°	0.1548	1564	1580	1596	1612	1629	1645	1661	1677	1694	3 5 8	11 14	
	56°	0.1710	1726	1743	1759	1776	1792	1809	1825	1842	1858	3 5 8	11 14	
	57°	0.1875	1891	1908	1925	1941	1958	1975	1992	2008	2025	3 5 8	11 14	
	58°	0.2042	2059	2076	2093	2110	2127	2144	2161	2178	2195	3 5 8	11 14	
	59°	0.2212	2229	2247	2264	2281	2299	2318	2333	2351	2368	3 5 8	12 14	
	60°	0.2386	2403	2421	2438	2456	2474	2491	2509	2527	2545	3 5 8	12 15	
	61°	0.2562	2580	2598	2616	2634	2652	2670	2689	2707	2725	3 5 8	12 15	
	62°	0.2743	2762	2780	2798	2817	2835	2854	2872	2891	2910	3 5 8	12 15	
	63°	0.2928	2947	2966	2985	3004	3023	3042	3061	3080	3099	3 5 8	13 16	
	64°	0.3118	3137	3157	3176	3198	3215	3234	3254	3274	3294	3 5 8	13 16	
	65°	0.3313	3333	3353	3373	3393	3413	3433	3453	3473	3494	3 7 10	13 17	
	66°	0.3514	3535	3555	3576	3596	3617	3638	3659	3679	3700	3 7 10	14 17	
	67°	0.3721	3743	3764	3785	3806	3828	3849	3871	3892	3914	4 7 11	14 18	
	68°	0.3936	3958	3980	4002	4024	4046	4068	4091	4113	4136	4 7 11	15 19	
	69°	0.4158	4181	4204	4227	4250	4273	4296	4319	4342	4366	4 8 12	15 19	
	70°	0.4389	4413	4437	4461	4484	4509	4533	4557	4581	4606	4 8 12	16 20	
	71°	0.4630	4655	4680	4705	4730	4755	4780	4805	4831	4857	4 8 13	17 21	
	72°	0.4882	4908	4934	4960	4986	5013	5039	5066	5093	5120	4 9 13	18 22	
	73°	0.5147	5174	5201	5229	5256	5284	5312	5340	5368	5397	5 9 14	19 23	
	74°	0.5425	5454	5483	5512	5541	5570	5600	5629	5659	5689	5 10 15	20 25	
	75°	0.5719	5750	5780	5811	5842	5873	5905	5938	5968	6000	5 10 16	21 26	
	76°	0.6032	6065	6097	6130	6163	6198	6230	6264	6298	6332	6 11 17	22 28	
	77°	0.6366	6401	6436	6471	6507	6542	6578	6615	6651	6688	6 12 18	24 30	
	78°	0.6725	6763	6800	6838	6877	6915	6954	6994	7033	7073	6 13 19	26 32	
	79°	0.7113	7154	7195	7236	7278	7320	7363	7406	7449	7493	7 14 21	28 35	
	80°	0.7537	7581	7626	7672	7718	7764	7811	7858	7906				

Circular or Radian Measure

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	0'	6'	12'	18'	24'	30'	36'	42'	48'	54'		
0°	0.0000	0017	0035	0052	0070	0087	0105	0122	0140	0157		
1	0.0175	0192	0209	0227	0244	0262	0279	0297	0314	0332		
2	0.0349	0367	0384	0401	0419	0436	0454	0471	0489	0506		
3	0.0524	0541	0559	0576	0593	0611	0628	0646	0663	0681		
4	0.0698	0716	0733	0750	0768	0785	0803	0820	0838	0855		
5	0.0873	0890	0908	0925	0942	0960	0977	0995	1012	1030		
6	0.1047	1065	1082	1100	1117	1134	1152	1169	1187	1204		
7	0.1222	1239	1257	1274	1292	1309	1326	1344	1361	1379		
8	0.1396	1414	1431	1449	1466	1484	1501	1518	1536	1553		
9	0.1571	1588	1606	1623	1641	1658	1676	1693	1710	1728		
10°	0.1745	1763	1780	1798	1815	1833	1850	1868	1885	1902		
11	0.1920	1937	1955	1972	1990	2007	2025	2042	2059	2077		
12	0.2094	2112	2129	2147	2164	2182	2199	2217	2234	2251		
13	0.2269	2286	2304	2321	2339	2356	2374	2391	2409	2426		
14	0.2443	2461	2478	2496	2513	2531	2548	2566	2583	2601		
15	0.2618	2635	2653	2670	2688	2705	2723	2740	2758	2775		
16	0.2793	2810	2827	2845	2862	2880	2897	2915	2932	2950		
17	0.2967	2985	3002	3019	3037	3054	3072	3089	3107	3124	Difference	
18	0.3142	3159	3176	3194	3211	3229	3246	3264	3281	3299		
19	0.3318	3334	3351	3368	3384	3403	3421	3438	3456	3473		
20°	0.3491	3508	3526	3543	3560	3578	3595	3613	3630	3648	for is	
								1'	3			
								2'	6			
21	0.3665	3683	3700	3718	3735	3752	3770	3787	3805	3822	3'	9
22	0.3840	3857	3875	3892	3910	3927	3944	3962	3979	3997	4'	12
23	0.4014	4032	4049	4067	4084	4102	4119	4136	4154	4171	5'	15
24	0.4189	4206	4224	4241	4259	4276	4294	4311	4328	4346		
25	0.4363	4381	4398	4416	4433	4451	4468	4485	4503	4520		
26	0.4538	4555	4573	4590	4608	4625	4643	4660	4677	4695		
27	0.4712	4730	4747	4765	4782	4800	4817	4835	4852	4869		
28	0.4887	4904	4922	4939	4957	4974	4992	5009	5027	5044		
29	0.5061	5079	5096	5114	5131	5149	5166	5184	5201	5219		
30°	0.5236	5253	5271	5288	5306	5323	5341	5358	5376	5393		
31	0.5411	5428	5445	5463	5480	5498	5515	5533	5550	5568		
32	0.5585	5603	5620	5637	5655	5672	5690	5707	5725	5742		
33	0.5760	5777	5794	5812	5829	5847	5864	5882	5899	5917		
34	0.5934	5952	5969	5986	6004	6021	6039	6056	6074	6091		
35	0.6109	6126	6144	6161	6178	6196	6213	6231	6248	6266		
36	0.6283	6301	6318	6336	6353	6370	6388	6405	6423	6440		
37	0.6458	6475	6493	6510	6528	6545	6562	6580	6597	6615		
38	0.6632	6650	6667	6685	6702	6720	6737	6754	6772	6789		
39	0.6807	6824	6842	6859	6877	6894	6912	6929	6946	6964		
40°	0.6981	6999	7016	7034	7051	7069	7086	7103	7121	7138		
41	0.7156	7173	7191	7208	7226	7243	7261	7278	7295	7313		
42	0.7330	7348	7365	7383	7400	7418	7435	7453	7470	7487		
43	0.7505	7522	7540	7557	7575	7592	7610	7627	7645	7662		
44	0.7679	7697	7714	7732	7749	7767	7784	7802	7819	7837		

Circular or Radian Measure

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	0'	6'	12'	18'	24'	30'	36'	42'	48'	54'		
45°	0.7854	7871	7889	7906	7924	7941	7959	7976	7994	8011		
46	0.8029	8046	8063	8081	8098	8116	8133	8151	8168	8186		
47	0.8203	8221	8238	8255	8273	8290	8308	8325	8343	8360		
48	0.8378	8395	8412	8430	8447	8465	8482	8500	8517	8525		
49	0.8552	8570	8587	8604	8622	8639	8657	8674	8692	8709		
50°	0.8727	8744	8762	8779	8796	8814	8831	8849	8866	8884		
51	0.8901	8919	8936	8954	8971	8988	9006	9023	9041	9058		
52	0.9076	9093	9111	9128	9146	9163	9180	9198	9215	9233		
53	0.9250	9268	9285	9303	9320	9338	9355	9372	9390	9407		
54	0.9425	9442	9460	9477	9495	9512	9529	9547	9564	9582		
55	0.9599	9617	9634	9652	9669	9687	9704	9721	9739	9756		
56	0.9774	9791	9809	9826	9844	9861	9879	9896	9913	9931	Difference	
57	0.9948	9966	9983	1-0001	1-0018	1-0036	1-0053	1-0071	1-0088	1-0105		
58	1-0123	1-0140	1-0158	1-0175	1-0193	1-0210	1-0228	1-0245	1-0263	1-0280		
59	1-0297	1-0315	1-0332	1-0350	1-0367	1-0385	1-0402	1-0420	1-0437	1-0455		
60°	1-0472	1-0489	1-0507	1-0524	1-0542	1-0559	1-0577	1-0594	1-0612	1-0629		
61	1-0647	1-0664	1-0681	1-0699	1-0716	1-0734	1-0751	1-0769	1-0786	1-0804		
62	1-0821	1-0838	1-0856	1-0873	1-0891	1-0908	1-0926	1-0943	1-0961	1-0978		
63	1-0996	1-1013	1-1030	1-1048	1-1065	1-1083	1-1100	1-1118	1-1135	1-1153		
64	1-1170	1-1188	1-1205	1-1222	1-1240	1-1257	1-1275	1-1292	1-1310	1-1327	for is	
65	1-1345	1-1362	1-1380	1-1397	1-1414	1-1432	1-1449	1-1467	1-1484	1-1502	1'	3
66	1-1519	1-1537	1-1554	1-1572	1-1589	1-1606	1-1624	1-1641	1-1659	1-1676	2'	6
67	1-1694	1-1711	1-1729	1-1746	1-1764	1-1781	1-1798	1-1816	1-1833	1-1851	4'	12
68	1-1868	1-1886	1-1903	1-1921	1-1938	1-1956	1-1973	1-1990	1-2008	1-2025	5'	15
69	1-2043	1-2060	1-2078	1-2095	1-2113	1-2130	1-2147	1-2165	1-2182	1-2200		
70°	1-2217	1-2235	1-2252	1-2270	1-2287	1-2305	1-2322	1-2339	1-2357	1-2374		
71	1-2392	1-2409	1-2427	1-2444	1-2462	1-2479	1-2497	1-2514	1-2531	1-2549		
72	1-2566	1-2584	1-2601	1-2619	1-2636	1-2654	1-2671	1-2689	1-2706	1-2723		
73	1-2741	1-2758	1-2776	1-2793	1-2811	1-2828	1-2846	1-2863	1-2881	1-2898		
74	1-2915	1-2933	1-2950	1-2968	1-2985	1-3003	1-3020	1-3038	1-3055	1-3073		
75	1-3080	1-3107	1-3125	1-3142	1-3160	1-3177	1-3195	1-3212	1-3230	1-3247		
76	1-3265	1-3282	1-3299	1-3317	1-3334	1-3352	1-3369	1-3387	1-3404	1-3422		
77	1-3439	1-3456	1-3474	1-3491	1-3509	1-3526	1-3544	1-3561	1-3579	1-3598		
78	1-3614	1-3631	1-3648	1-3666	1-3683	1-3701	1-3718	1-3736	1-3753	1-3771		
79	1-3788	1-3805	1-3823	1-3840	1-3858	1-3875	1-3893	1-3910	1-3928	1-3945		
80°	1-3963	1-3980	1-3998	1-4015	1-4032	1-4050	1-4067	1-4083	1-4102	1-4120		
81	1-4137	1-4155	1-4172	1-4190	1-4207	1-4224	1-4242	1-4259	1-4277	1-4294		
82	1-4312	1-4329	1-4347	1-4364	1-4382	1-4399	1-4416	1-4434	1-4451	1-4469		
83	1-4486	1-4504	1-4521	1-4539	1-4556	1-4573	1-4591	1-4608	1-4626	1-4643		
84	1-4661	1-4678	1-4696	1-4713	1-4731	1-4748	1-4765	1-4783	1-4800	1-4818		
85	1-4835	1-4853	1-4870	1-4888	1-4905	1-4923	1-4940	1-4957	1-4975	1-4992		
86	1-5010	1-5027	1-5045	1-5062	1-5080	1-5097	1-5115	1-5132	1-5149	1-5167		
87	1-5184	1-5202	1-5219	1-5237	1-5254	1-5272	1-5289	1-5307	1-5324	1-5341		
88	1-5359	1-5376	1-5394	1-5411	1-5429	1-5446	1-5464	1-5481	1-5499	1-5516		
89	1-5533	1-5551	1-5568	1-5586	1-5603	1-5621	1-5638	1-5656	1-5673	1-5691		

Squares

22

	0	1	2	3	4	5	6	7	8	9
0	0	1	4	9	16	25	36	49	64	81
1	100	121	144	169	196	225	256	289	324	361
2	400	441	484	529	576	625	676	729	784	841
3	900	961	1024	1089	1156	1225	1296	1369	1444	1521
4	1600	1681	1764	1849	1936	2025	2116	2209	2304	2401
5	2500	2601	2704	2809	2916	3025	3136	3249	3364	3481
6	3600	3721	3844	3969	4096	4225	4356	4489	4624	4761
7	4900	5041	5184	5329	5476	5625	5776	5929	6084	6241
8	6400	6561	6724	6889	7056	7225	7396	7569	7744	7921
9	8100	8281	8464	8649	8836	9025	9216	9409	9604	9801
10	10000	10201	10404	10609	10816	11025	11236	11449	11664	11881
11	12100	12321	12544	12769	12996	13225	13456	13689	13924	14161
12	14400	14641	14884	15129	15376	15625	15876	16129	16384	16641
13	16900	17161	17424	17689	17956	18225	18496	18769	19044	19321
14	19600	19881	20164	20449	20736	21025	21316	21609	21904	22201
15	22500	22801	23104	23409	23716	24025	24336	24649	24964	25281
16	25600	25921	26244	26569	26895	27225	27556	27889	28224	28561
17	28900	29241	29584	29929	30276	30625	30976	31329	31684	32041
18	32400	32761	33124	33489	33856	34225	34596	34969	35344	35721
19	36100	36481	36864	37249	37636	38025	38416	38809	39204	39601
20	40000	40401	40804	41209	41616	42025	42436	42849	43264	43681
21	44100	44521	44944	45369	45798	46225	46656	47089	47524	47961
22	48400	48841	49284	49729	50176	50625	51076	51529	51984	52441
23	52900	53361	53824	54289	54756	55225	55696	56169	56644	57121
24	57600	58091	58564	59049	59536	60025	60516	61009	61504	62001
25	62500	63001	63504	64009	64516	65025	65536	66049	66564	67081
26	67600	68121	68644	69169	69696	70225	70756	71289	71824	72351
27	72900	73441	73984	74529	75076	75625	76176	76729	77284	77841
28	78400	78961	79524	80089	80656	81225	81796	82369	82944	83521
29	84100	84881	85564	86244	86936	87625	88316	89009	89601	90201
30	90000	90801	91204	91809	92416	93025	93636	94249	94864	95481
31	96100	96721	97344	97969	98596	99225	99856	100489	101124	101761
32	102400	103041	103684	104329	104976	105625	106276	106929	107584	108241
33	108900	109561	110224	110889	111556	112225	112898	113569	114244	114921
34	115600	116281	116964	117649	118336	119025	119716	120409	121104	121801
35	122500	123201	123904	124609	125316	126025	126736	127449	128164	128881
36	129500	130321	131044	131769	132496	133225	133956	134689	135424	136161
37	136900	137641	138384	139129	139876	140625	141376	142129	142884	143641
38	144400	145161	145924	146689	147456	148225	148996	149769	150544	151321
39	152100	152881	153664	154449	155236	156025	156816	157609	158404	159201
40	160000	161604	162409	163216	164025	164836	165649	166464	167281	168100
41	168100	169744	170569	171396	172225	173056	173889	174724	175561	176400
42	176400	177241	178084	178929	179776	180625	181476	182329	183184	184041
43	184900	185761	186624	187489	188356	189225	190096	191864	192721	193581
44	193600	194481	195354	196249	197136	198025	198916	199809	200704	201601
45	202500	203401	204304	205209	206116	207025	207936	208849	209764	210681
46	211600	212521	213444	214369	215296	216225	217156	218089	219024	219961
47	220900	221841	222784	223729	224676	225625	226576	227529	228484	229441
48	230400	231361	232324	233289	234256	235225	236196	237169	238144	239121
49	240100	241081	242064	243049	244038	245025	246016	247009	248004	249001

Exact squares of 4 figure numbers can be quickly calculated from the Identity
 $(a \pm b)^2 = a^2 \pm 2ab + b^2$.

Squares

23

	0	1	2	3	4	5	6	7	8	9
50	250000	251001	252004	253009	254016	255025	256036	257049	258064	259081
51	260100	261121	262144	263169	264193	265225	266256	267289	268324	269361
52	270400	271441	272484	273529	274576	275625	276676	277729	278784	279841
53	280900	281961	283024	284089	285156	286225	287296	288369	289444	290521
54	291600	292681	293764	294849	295936	297025	298116	299209	300304	301401
55	302500	303601	304704	305808	306916	308025	309136	310249	311364	312481
56	313600	314721	315844	316969	318096	319225	320356	321489	322624	323757
57	324900	326041	327184	328329	329476	330625	331776	332929	334084	335241
58	336400	337561	338724	339891	341056	342225	343396	344569	345744	346921
59	348100	349281	350464	351649	352836	354025	355216	356409	357604	358801
60	360000	361201	362404	363609	364816	366025	367236	368449	369664	370881
61	372100	373321	374544	375769	376996	378225	379456	380689	381924	383161
62	384400	385641	386864	388092	389325	390525	391767	393128	394364	395641
63	396900	398161	399424	400689	401956	403225	404498	405769	407044	408321
64	409600	410881	412104	413449	414783	416025	417316	418609	419904	421201
65	422500	423801	425104	426409	427716	429025	430336	431649	432964	434281
66	435600	436921	438244	439569	440896	442225	443556	444889	446224	447551
67	448900	450241	451584	452929	454276	455625	456976	458329	459684	461041
68	462400	463761	465124	466489	467856	469225	470596	471989	473344	474721
69	476100	477481	478864	480249	481636	483025	484416	485809	487204	488601
70	490000	491401	492804	494209	495616	497025	498436	499849	501264	502681
71	504100	505521	506944	508369	509793	511225	512656	514089	515524	516961
72	518400	519841	521284	522729	524176	525625	527076	528529	529984	531441
73	532900	534361	535824	537289	538756	540225	541698	543169	544644	546121
74	547600	549081	550564	552049	553536	555025	556516	558009	559504	561001
75	562500	564001	565504	567009	568516	570025	571536	573049	574564	576081
76	577600	579121	580644	582169	583696	585225	586763	588299	589824	591361
77	592900	594441	595984	597529	599076	600525	602176	603729	605264	606841
78	608400	609861	611254	613089	614656	616225	617796	619369	620944	622521
79	624100	625681	627264	628849	630436	632025	633616	635209	636804	638401
80	640000	641601	643204	644809	646416	648025	649636	651249	652864	654481
81	656100	657721	659344	660969	662596	664225	665856	667489	669124	670761
82	672400	674041	675684	677329	678976	680625	682276	683929	685564	687241
83	688900	690561	692224	693899	695556	697225	698896	700569	702241	703921
84	705600	707281	708964	710649	712336	714025	715716	717409	719104	720801
85	722500	724201	725904	727609	729318	731025	732738	734440	736164	737881
86	739600	741321	743044	744769	746496	748225	749956	751689	753424	755161
87	756900	758641	760394	762129	763876	765625	767376	769129	770884	772641
88	774400	776161	777924	779689	781456	783225	784996	786769	788544	790321
89	792100	793861	795634	797449	799236	801025	802816	804609	806404	808201
90	810000	811801	813604	815409	817216	819025	820836	822646	824464	826281
91	828100	829941	831744	833593	835393	837225	839056	840889	842724	844561
92	846400	848241	850084	851929	853776	855525	857476	859329	861124	863041
93	864900	866761	868624	870489	872356	874225	876096	877936	879844	881721
94	883600	885481	887364	889249	891136	893025	894916	896809	898704	900601
95	902500	904401	906304	908209	910116	912025	913936	915849	917764	919691
96	921600	923521	925444	927369	929298	931225	933156	935089	937024	938951
97	940800	942841	944784	946729	948676	950525	952576	954529	956454	958441
98	960400	962361	964324							

Square Roots from 1 to 10

24

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
1-0	1-000	1-005	1-010	1-015	1-020	1-025	1-030	1-034	1-039	1-044	0	1	1	2	2	3	3	4	4
1-1	1-049	1-054	1-058	1-063	1-068	1-072	1-077	1-082	1-086	1-091	0	1	1	2	2	3	3	4	4
1-2	1-095	1-100	1-105	1-109	1-114	1-118	1-123	1-127	1-131	1-136	0	1	1	2	2	3	3	4	4
1-3	1-140	1-145	1-149	1-153	1-158	1-162	1-166	1-171	1-175	1-179	0	1	1	2	2	3	3	3	4
1-4	1-183	1-187	1-192	1-195	1-200	1-204	1-208	1-212	1-217	1-221	0	1	1	2	2	3	3	3	4
1-5	1-225	1-229	1-233	1-237	1-241	1-245	1-249	1-253	1-257	1-261	0	1	1	2	2	2	3	3	4
1-6	1-265	1-269	1-273	1-277	1-281	1-285	1-288	1-292	1-296	1-300	0	1	1	2	2	2	3	3	3
1-7	1-304	1-308	1-312	1-315	1-319	1-323	1-327	1-330	1-334	1-338	0	1	1	2	2	2	3	3	3
1-8	1-342	1-345	1-349	1-353	1-357	1-360	1-364	1-368	1-371	1-375	0	1	1	1	2	2	3	3	3
1-9	1-378	1-382	1-386	1-389	1-393	1-396	1-400	1-404	1-407	1-411	0	1	1	1	2	2	3	3	3
2-0	1-414	1-418	1-421	1-425	1-428	1-432	1-435	1-439	1-442	1-446	0	1	1	1	2	2	2	3	3
2-1	1-449	1-453	1-456	1-460	1-463	1-466	1-470	1-473	1-477	1-480	0	1	1	1	2	2	2	3	3
2-2	1-483	1-487	1-490	1-493	1-497	1-500	1-503	1-507	1-510	1-513	0	1	1	1	2	2	2	3	3
2-3	1-517	1-520	1-523	1-525	1-530	1-533	1-536	1-539	1-543	1-546	0	1	1	1	2	2	2	3	3
2-4	1-540	1-552	1-556	1-559	1-562	1-565	1-568	1-572	1-575	1-578	0	1	1	1	2	2	2	3	3
2-5	1-581	1-584	1-587	1-591	1-594	1-597	1-600	1-603	1-606	1-609	0	1	1	1	2	2	2	3	3
2-6	1-612	1-616	1-619	1-622	1-625	1-628	1-631	1-634	1-637	1-640	0	1	1	1	2	2	2	3	3
2-7	1-643	1-646	1-649	1-652	1-655	1-658	1-661	1-664	1-667	1-670	0	1	1	1	2	2	2	3	3
2-8	1-673	1-676	1-679	1-682	1-685	1-688	1-691	1-694	1-697	1-700	0	1	1	1	1	2	2	2	3
2-9	1-703	1-706	1-709	1-712	1-715	1-718	1-720	1-723	1-726	1-729	0	1	1	1	1	2	2	2	3
3-0	1-732	1-735	1-738	1-741	1-744	1-746	1-749	1-752	1-755	1-758	0	1	1	1	1	2	2	2	3
3-1	1-761	1-764	1-766	1-769	1-772	1-775	1-778	1-780	1-783	1-786	0	1	1	1	1	2	2	2	3
3-2	1-789	1-792	1-794	1-797	1-800	1-803	1-806	1-808	1-811	1-814	0	1	1	1	1	2	2	2	3
3-3	1-817	1-819	1-822	1-825	1-828	1-830	1-833	1-836	1-839	1-841	0	1	1	1	1	2	2	2	2
3-4	1-844	1-847	1-849	1-852	1-855	1-857	1-860	1-863	1-866	1-868	0	1	1	1	1	2	2	2	2
3-5	1-871	1-874	1-876	1-879	1-882	1-884	1-887	1-889	1-892	1-895	0	1	1	1	1	2	2	2	2
3-6	1-897	1-900	1-903	1-905	1-908	1-911	1-913	1-916	1-918	1-921	0	1	1	1	1	2	2	2	2
3-7	1-924	1-926	1-929	1-931	1-934	1-937	1-939	1-942	1-944	1-947	0	1	1	1	1	2	2	2	2
3-8	1-949	1-952	1-955	1-957	1-960	1-962	1-965	1-967	1-970	1-972	0	1	1	1	1	2	2	2	2
3-9	1-975	1-977	1-980	1-982	1-985	1-988	1-990	1-993	1-995	1-998	0	1	1	1	1	2	2	2	2
4-0	2-000	2-003	2-006	2-010	2-013	2-015	2-017	2-020	2-022	2-024	0	0	1	1	1	1	2	2	2
4-1	2-025	2-027	2-030	2-032	2-035	2-037	2-040	2-042	2-045	2-047	0	0	1	1	1	1	2	2	2
4-2	2-049	2-052	2-054	2-057	2-059	2-062	2-064	2-066	2-069	2-071	0	0	1	1	1	1	2	2	2
4-3	2-074	2-076	2-078	2-081	2-083	2-086	2-088	2-091	2-093	2-095	0	0	1	1	1	1	2	2	2
4-4	2-098	2-100	2-102	2-105	2-107	2-110	2-112	2-114	2-117	2-119	0	0	1	1	1	1	2	2	2
4-5	2-121	2-124	2-126	2-128	2-131	2-133	2-135	2-138	2-140	2-142	0	0	1	1	1	1	2	2	2
4-6	2-145	2-147	2-149	2-152	2-154	2-156	2-159	2-161	2-163	2-166	0	0	1	1	1	1	2	2	2
4-7	2-168	2-170	2-173	2-175	2-177	2-179	2-182	2-184	2-186	2-189	0	0	1	1	1	1	2	2	2
4-8	2-191	2-193	2-195	2-198	2-200	2-202	2-205	2-207	2-209	2-211	0	0	1	1	1	1	2	2	2
4-9	2-214	2-216	2-218	2-220	2-223	2-225	2-227	2-229	2-232	2-234	0	0	1	1	1	1	2	2	2
5-0	2-236	2-238	2-241	2-243	2-245	2-247	2-249	2-252	2-254	2-256	0	0	1	1	1	1	2	2	2
5-1	2-259	2-261	2-263	2-265	2-267	2-269	2-272	2-274	2-276	2-278	0	0	1	1	1	1	2	2	2
5-2	2-280	2-283	2-285	2-287	2-289	2-291	2-294	2-296	2-298	2-300	0	0	1	1	1	1	2	2	2
5-3	2-302	2-304	2-307	2-309	2-311	2-313	2-315	2-317	2-320	2-322	0	0	1	1	1	1	2	2	2
5-4	2-324	2-326	2-328	2-330	2-332	2-335	2-337	2-339	2-341	2-343	0	0	1	1	1	1	2	2	2

Square Roots from 1 to 10

25

	0	1	2	3	4	5	6	7	8	9	Mean Differences									
											1	2	3	4	5	6	7	8	9	
5-5	2-345	2-347	2-350	2-352	2-354	2-356	2-358	2-360	2-362	2-364	0	0	1	1	1	1	1	1	1	1
5-6	2-365	2-369	2-371	2-373	2-375	2-377	2-379	2-381	2-383	2-385	0	0	1	1	1	1	1	1	1	1
5-7	2-388	2-390	2-392	2-394	2-396	2-398	2-400	2-402	2-404	2-406	0	0	1	1	1	1	1	1	1	1
5-8	2-408	2-410	2-412	2-415	2-417	2-419	2-421	2-423	2-425	2-427	0	0	1	1	1	1	1	1	1	1
5-9	2-429	2-431	2-433	2-435	2-437	2-439	2-441	2-443	2-445	2-447	0	0	1	1	1	1	1	1	1	1
6-0	2-450	2-452	2-454	2-456	2-458	2-460	2-462	2-464	2-466	2-468	0	0	1	1	1	1	1	1	1	1
6-1	2-470	2-472	2-474	2-476	2-478	2-480	2-482	2-484	2-486	2-488	0	0	1	1	1	1	1	1	1	1
6-2	2-490	2-492	2-494	2-496	2-498	2-500	2-502	2-504	2-506	2-508	0	0	1	1	1	1	1	1	1	1
6-3	2-510	2-512	2-514	2-516	2-518	2-520	2-522	2-524	2-526	2-528	0	0	1	1	1	1	1	1	1	1
6-4	2-530	2-532	2-534	2-536	2-538	2-540	2-542	2-544	2-546	2-548	0	0	1	1	1	1	1	1	1	1
6-5	2-550	2-551	2-553	2-555	2-557	2-559	2-561	2-563	2-565	2-567	0	0	1	1	1	1	1	1	1	1
6-6	2-569	2-571	2-573	2-575	2-577	2-579	2-581	2-583	2-585	2-587	0	0	1	1	1	1	1	1	1	1
6-7	2-588	2-590	2-592	2-594	2-596	2-598	2-600	2-602	2-604	2-606	0	0	1	1	1	1	1	1	1	1
6-8	2-620	2-622	2-624	2-626	2-628	2-630	2-632	2-634	2-636	2-638	0	0	1	1	1	1	1	1	1	1
6-9	2-640	2-642	2-644	2-646	2-648	2-650	2-652	2-654	2-656	2-658	0	0	1	1	1	1	1	1	1	1
7-0	2-668	2-670	2-672	2-674	2-676	2-678	2-680	2-682	2-684	2-686	0	0	1	1	1	1	1	1	1	1
7-1	2-685	2-687	2-689	2-691	2-693	2-695	2-697	2-699	2-701	2-703	0	0	1	1	1	1	1	1	1	1
7-2	2-703	2-707	2-711	2-715	2-719	2-723	2-727	2-731	2-735	2-739	0	0	1	1	1	1	1	1	1	1
7-3	2-720	2-724	2-728	2-732</																

Square Roots from 10 to 100

26

	Mean Differences										
	0	1	2	3	4	5	6	7	8	9	
	1	2	3	4	5	6	7	8	9	0	
10	3-162	3-178	3-194	3-209	3-225	3-240	3-256	3-271	3-286	3-302	2 3 5 6 8 9 11 12 14
11	3-317	3-332	3-347	3-362	3-376	3-391	3-406	3-421	3-435	3-450	1 3 4 6 7 9 10 12 13
12	3-484	3-479	3-493	3-507	3-521	3-536	3-550	3-564	3-578	3-592	1 3 4 6 7 8 10 11 13
13	3-606	3-619	3-633	3-647	3-661	3-674	3-688	3-701	3-715	3-728	1 3 4 5 7 8 10 11 12
14	3-742	3-755	3-768	3-782	3-795	3-809	3-821	3-834	3-847	3-860	1 3 4 5 7 8 9 11 12
15	3-873	3-886	3-899	3-912	3-924	3-937	3-950	3-962	3-975	3-988	1 3 4 5 6 8 9 10 11
16	4-000	4-012	4-025	4-037	4-050	4-062	4-074	4-087	4-099	4-111	1 2 4 5 6 7 8 9 10 11
17	4-123	4-135	4-147	4-159	4-171	4-183	4-195	4-207	4-219	4-231	1 2 4 5 6 7 8 10 11
18	4-243	4-254	4-266	4-278	4-290	4-301	4-313	4-324	4-336	4-347	1 2 3 5 6 7 8 9 10
19	4-359	4-370	4-382	4-393	4-405	4-416	4-427	4-438	4-450	4-461	1 2 3 5 6 7 8 9 10
20	4-472	4-483	4-494	4-506	4-517	4-528	4-539	4-550	4-561	4-572	1 2 3 4 6 7 8 9 10
21	4-583	4-594	4-604	4-615	4-626	4-637	4-648	4-658	4-669	4-680	1 2 3 4 5 6 8 9 10
22	4-690	4-701	4-712	4-722	4-733	4-743	4-754	4-765	4-775	4-785	1 2 3 4 5 6 7 8 9
23	4-796	4-808	4-817	4-827	4-837	4-848	4-858	4-868	4-879	4-889	1 2 3 4 5 6 7 8 9
24	4-899	4-909	4-919	4-930	4-940	4-950	4-960	4-970	4-980	4-990	1 2 3 4 5 6 7 8 9
25	5-000	5-010	5-020	5-030	5-040	5-050	5-060	5-070	5-079	5-089	1 2 3 4 5 6 7 8 9
26	5-059	5-109	5-119	5-128	5-138	5-148	5-159	5-167	5-177	5-187	1 2 3 4 5 6 7 8 9
27	5-196	5-206	5-215	5-225	5-235	5-244	5-254	5-263	5-273	5-282	1 2 3 4 5 6 7 8 9
28	5-292	5-301	5-310	5-320	5-329	5-339	5-348	5-357	5-367	5-376	1 2 3 4 5 6 7 8 9
29	5-385	5-394	5-404	5-413	5-422	5-431	5-441	5-450	5-459	5-468	1 2 3 4 5 5 6 7 8
30	5-477	5-488	5-495	5-505	5-514	5-523	5-532	5-541	5-550	5-559	1 2 3 4 4 5 6 7 8
31	5-568	5-577	5-586	5-595	5-604	5-612	5-621	5-630	5-639	5-648	1 2 3 3 4 5 6 7 8
32	5-657	5-666	5-675	5-683	5-692	5-701	5-710	5-718	5-727	5-736	1 2 3 3 4 5 6 7 8
33	5-745	5-753	5-762	5-771	5-779	5-788	5-797	5-805	5-814	5-822	1 2 3 3 4 5 6 7 8
34	5-831	5-840	5-848	5-857	5-865	5-874	5-882	5-891	5-899	5-908	1 2 3 3 4 5 6 7 8
35	5-916	5-925	5-933	5-941	5-950	5-958	5-967	5-975	5-983	5-992	1 2 2 3 4 5 6 7 8
36	6-000	6-008	6-017	6-025	6-033	6-042	6-050	6-058	6-066	6-075	1 2 2 3 4 5 6 7 7
37	6-083	6-091	6-099	6-107	6-116	6-124	6-132	6-140	6-148	6-156	1 2 2 3 4 5 6 7 7
38	6-164	6-173	6-181	6-189	6-197	6-205	6-213	6-221	6-229	6-237	1 2 2 3 4 5 6 7 7
39	6-245	6-253	6-261	6-269	6-277	6-285	6-293	6-301	6-309	6-317	1 2 2 3 4 5 6 6 7
40	6-325	6-332	6-340	6-348	6-356	6-364	6-372	6-380	6-387	6-395	1 2 2 3 4 5 6 6 7
41	6-403	6-411	6-419	6-427	6-434	6-442	6-450	6-458	6-465	6-473	1 2 2 3 4 5 5 6 7
42	6-481	6-488	6-495	6-504	6-512	6-519	6-527	6-535	6-542	6-550	1 2 2 3 4 5 5 6 7
43	6-557	6-565	6-573	6-580	6-588	6-595	6-603	6-611	6-618	6-626	1 2 2 3 4 5 5 6 7
44	6-633	6-641	6-648	6-656	6-663	6-671	6-678	6-686	6-693	6-701	1 2 2 3 4 5 5 6 7
45	6-708	6-716	6-723	6-731	6-738	6-745	6-753	6-760	6-768	6-775	1 1 2 3 4 4 5 6 7
46	6-782	6-790	6-797	6-804	6-812	6-819	6-826	6-834	6-841	6-848	1 1 2 3 4 4 5 6 7
47	6-856	6-863	6-870	6-878	6-885	6-892	6-899	6-907	6-914	6-921	1 1 2 3 4 4 5 6 7
48	6-928	6-935	6-943	6-950	6-957	6-964	6-971	6-979	6-986	6-993	1 1 2 3 4 4 5 6 6
49	7-000	7-007	7-014	7-021	7-029	7-036	7-043	7-050	7-057	7-064	1 1 2 3 4 4 5 6 6
50	7-071	7-078	7-085	7-092	7-099	7-106	7-113	7-120	7-127	7-134	1 1 2 3 4 4 5 6 6
51	7-141	7-148	7-155	7-162	7-169	7-176	7-183	7-190	7-197	7-204	1 1 2 3 4 4 5 6 6
52	7-211	7-218	7-225	7-232	7-239	7-246	7-253	7-259	7-266	7-273	1 1 2 3 4 4 5 6 6
53	7-280	7-287	7-294	7-301	7-308	7-314	7-321	7-328	7-335	7-342	1 1 2 3 4 4 5 5 6
54	7-349	7-355	7-362	7-369	7-376	7-382	7-389	7-396	7-403	7-410	1 1 2 3 4 4 5 5 6

Square Roots from 10 to 100

27

	Mean Differences										
	0	1	2	3	4	5	6	7	8	9	
	1	2	3	4	5	6	7	8	9	0	
55	7-416	7-423	7-430	7-436	7-443	7-450	7-457	7-463	7-470	7-477	1 1 2 3 3 4 4 5 5 6
56	7-483	7-490	7-497	7-510	7-517	7-523	7-530	7-537	7-543	7-549	1 1 2 3 3 4 4 5 5 6
57	7-550	7-558	7-563	7-570	7-576	7-583	7-590	7-603	7-609	7-615	1 1 2 3 3 4 4 5 5 6
58	7-616	7-622	7-629	7-635	7-642	7-649	7-655	7-662	7-668	7-675	1 1 2 3 3 4 4 5 5 6
59	7-681	7-688	7-694	7-701	7-707	7-714	7-720	7-727	7-733	7-740	1 1 2 3 3 4 4 5 5 6
60	7-746	7-752	7-759	7-765	7-772	7-778	7-785	7-791	7-797	7-804	1 1 2 3 3 4 4 5 5 6
61	7-810	7-817	7-823	7-829	7-842	7-849	7-855	7-861	7-868	7-875	1 1 2 3 3 4 4 5 5 6
62	7-874	7-880	7-887	7-893	7-908	7-912	7-918	7-925	7-931	7-937	1 1 2 3 3 4 4 5 5 6
63	7-937	7-944	7-950	7-956	7-962	7-969	7-975	7-981	7-987	7-994	1 1 2 3 3 4 4 5 5 6
64	8-000	8-008	8-012	8-019	8-025	8-031	8-037	8-044	8-050	8-056	1 1 2 3 3 4 4 5 5 6
65	8-062	8-068	8-075	8-081	8-087	8-093	8-099	8-106	8-112	8-118	1 1 2 3 3 4 4 5 5 6
66	8-124	8-130	8-136	8-142	8-149	8-155	8-161	8-167	8-173	8-179	1 1 2 3 3 4 4 5 5 6
67	8-185	8-191	8-198	8-204	8-210	8-216	8-222	8-228	8-234	8-240	1 1 2 3 3 4 4 5 5 6
68	8-246	8-252	8-258	8-264	8-270	8-276	8-283	8-289	8-295	8-301	1 1 2 3 3 4 4 5 5 6
69	8-307	8-313	8-319	8-325	8-331	8-337	8-343	8-349	8-355	8-361	1 1 2 3 3 4 4 5 5 6
70	8-367	8-373	8-379	8-385	8-390	8-396	8-402	8-408	8-414	8-420	1 1 2 3 3 4 4 5 5 6
71	8-426	8-432	8-438	8-444	8-450	8-456	8-462	8-468	8-473	8-479	1 1 2 3 3 4 4 5 5 6
72	8-485	8-491	8-497	8-503	8-509	8-515	8-521	8-528	8-533	8-539	1 1 2 3 3 4 4 5 5 6
73	8-544	8-550	8-556	8-562	8-567	8-573	8-579	8-585	8-591	8-597	1 1 2 3 3 4 4 5 5 6
74	8-602	8-608	8-614	8-620	8-626	8-631	8-637	8-643	8-649	8-654	1 1 2 3 3 4 4 5 5 6
75	8-660	8-666	8-672	8-678	8-683	8-689	8-695	8-701	8-707	8-712	1 1 2 3 3 4 4 5 5 6
76	8-718	8-724	8-729	8-735	8-741	8-748	8-752	8-758	8-764	8-769	1 1 2 3 3 4 4 5 5 6
77	8-775	8-781	8-786	8-792	8-798	8-803	8-809	8-815	8-820	8-826	1 1 2 3 3 4 4 5 5 6
78	8-832	8-837	8-843	8-849	8-854	8-860	8-866	8-871	8-877	8-883	1 1 2 3 3 4 4 5 5 6
79	8-884	8-894	8-899	8-905	8-911	8-916	8-922	8-927	8-933	8-939	1 1 2 3 3 4 4 5 5 6
80	8-944	8-950	8-955	8-961	8-967	8-972	8-978	8-983	8-989	8-994	1 1 2 3 3 4 4 5 5 6
81	9-000	9-006	9-011	9-017	9-022	9-028	9-033	9-039	9-044	9-050	1 1 2 3 3 4 4 5 5 6
82	9-055	9-061	9-066	9-072	9-077	9-083	9-089	9-094	9-099	9-105	1 1 2 3 3 4 4 5 5 6
83	9-110	9-116	9-121	9-127	9-133	9-139	9-145	9-149	9-154	9-160	1 1 2 3 3 4 4 5 5 6
84	9-165	9-171	9-176	9-182	9-187	9-192	9-198	9-203	9-209	9-214	1 1 2 3 3 4 4 5 5 6
85	9-220	9-225	9-230	9-236	9-241	9-247	9-252	9-257	9-263	9-268	1 1 2 3 3 4 4 5 5 6
86	9-274	9-279	9-284	9-290	9-295	9-301	9-306	9-311	9-317	9-322	1 1 2 3 3 4 4 5 5 6
87	9-327	9-333	9-338	9-343	9-349	9-354	9-359	9-365	9-370	9-375	1 1 2 3 3 4 4 5 5 6
88	9-381	9-386	9-391	9-397	9-402	9-407	9-413	9-418	9-423	9-428	1 1 2 3 3 4 4 5 5 6
89	9-434	9-439	9-445	9-450	9-455	9-460	9-466	9-471	9-476	9-482	1 1 2 3 3 4 4 5 5 6
90	9-487	9-492	9-497	9-503	9-508	9-513	9-518	9-524	9-529	9-534	1 1 2 3 3 4 4 5 5 6
91	9-539	9-545	9-550	9-555	9-560	9-566	9-5				

Reciprocals of Four-Figure Numbers

28

	SUBTRACT Mean Differences									
	0	1	2	3	4	5	6	7	8	9
	1	2	3	4	5	6	7	8	9	
1-0	1-000	9201	9204	9709	9615	9524	9434	9346	9259	9174
1-1	0-9091	9009	8929	8850	8772	8693	8621	8547	8475	8403
1-2	0-8333	8264	8187	8130	8065	8000	7937	7874	7813	7752
1-3	0-7093	7634	7576	7519	7463	7407	7353	7292	7246	7194
1-4	0-7143	7092	7042	6993	6944	6897	6849	6803	6757	6711
1-5	0-6887	6823	6779	6539	6484	6432	6410	6369	6329	6289
1-6	0-6250	6211	6173	6135	6098	6051	6024	5988	5952	5917
1-7	0-5882	5842	5814	5780	5747	5714	5688	5650	5618	5587
1-8	0-5556	5525	5485	5464	5435	5405	5376	5348	5319	5291
1-9	0-5283	5238	5208	5181	5155	5128	5102	5076	5051	5025
2-0	0-5000	4975	4950	4926	4902	4876	4854	4831	4808	4785
2-1	0-4762	4732	4717	4695	4673	4651	4630	4608	4587	4566
2-2	0-4545	4525	4505	4484	4464	4444	4425	4405	4386	4367
2-3	0-4348	4329	4310	4292	4274	4255	4237	4219	4202	4184
2-4	0-4167	4140	4132	4115	4093	4072	4055	4039	4022	4016
2-5	0-4000	3984	3962	3863	3837	3822	3808	3891	3876	3861
2-6	0-3846	3831	3817	3802	3785	3774	3759	3745	3731	3717
2-7	0-3704	3680	3670	3663	3550	3533	3523	3510	3507	3504
2-8	0-3571	3559	3542	3534	3521	3509	3497	3484	3472	3460
2-9	0-3448	3436	3425	3413	3401	3389	3378	3367	3356	3344
3-0	0-3333	3322	3311	3300	3289	3279	3265	3257	3247	3235
3-1	0-3226	3215	3205	3195	3185	3175	3165	3155	3145	3135
3-2	0-3125	3115	3105	3096	3085	3077	3067	3058	3049	3040
3-3	0-3030	3021	3012	3003	2994	2985	2976	2967	2959	2950
3-4	0-2941	2933	2924	2915	2907	2900	2890	2882	2874	2865
3-5	0-2857	2840	2841	2833	2825	2817	2809	2801	2793	2786
3-6	0-2770	2770	2753	2747	2740	2732	2725	2717	2710	
3-7	0-2703	2695	2688	2681	2674	2667	2660	2653	2646	2639
3-8	0-2632	2625	2618	2611	2604	2597	2591	2584	2577	2571
3-9	0-2584	2558	2551	2545	2538	2532	2525	2519	2513	2506
4-0	0-2500	2494	2488	2481	2475	2469	2463	2457	2451	2445
4-1	0-2439	2432	2427	2421	2415	2410	2404	2398	2392	2387
4-2	0-2381	2375	2370	2364	2358	2353	2347	2342	2336	2331
4-3	0-2326	2320	2315	2309	2304	2299	2284	2288	2283	2278
4-4	0-2373	2268	2262	2257	2252	2247	2242	2237	2232	2227
4-5	0-2222	2217	2212	2208	2203	2198	2193	2188	2183	2179
4-6	0-2174	2169	2165	2160	2155	2151	2146	2141	2137	2132
4-7	0-2128	2123	2119	2114	2110	2105	2101	2096	2092	2088
4-8	0-2083	2078	2075	2070	2066	2062	2058	2053	2049	2045
4-9	0-2041	2037	2033	2028	2024	2020	2016	2012	2008	2004
5-0	0-2000	1993	1992	1988	1984	1980	1976	1972	1969	1965
5-1	0-1981	1957	1953	1949	1946	1942	1938	1934	1931	1927
5-2	0-1923	1919	1916	1912	1908	1905	1901	1898	1894	1890
5-3	0-1887	1863	1860	1876	1873	1869	1865	1862	1859	1855
5-4	0-1852	1848	1845	1842	1838	1835	1832	1828	1825	1821

e.g. $\frac{1}{37} = 0.2703, \frac{1}{3.74} = 0.2374, \frac{1}{374.6} = 0.2668, \frac{1}{374.6} = 0.002668, \frac{1}{0.003748} = 2668.$

Reciprocals of Four-Figure Numbers

29

	SUBTRACT Mean Differences									
	0	1	2	3	4	5	6	7	8	9
	1	2	3	4	5	6	7	8	9	
5-5	0-1818	1815	1812	1808	1805	1802	1799	1795	1792	1789
5-6	0-1786	1783	1779	1776	1773	1770	1767	1764	1761	1757
5-7	0-1754	1751	1748	1745	1742	1739	1736	1733	1730	1727
5-8	0-1724	1721	1718	1715	1712	1709	1706	1704	1701	1698
5-9	0-1695	1692	1689	1686	1684	1681	1678	1675	1672	1669
6-0	0-1667	1664	1661	1658	1656	1653	1650	1647	1645	1642
6-1	0-1639	1637	1634	1631	1629	1626	1623	1621	1618	1616
6-2	0-1613	1610	1608	1605	1603	1600	1597	1595	1592	1590
6-3	0-1587	1585	1582	1580	1577	1575	1572	1570	1567	1565
6-4	0-1562	1560	1558	1555	1553	1550	1548	1546	1543	1541
6-5	0-1538	1536	1534	1531	1529	1527	1524	1522	1517	1517
6-6	0-1515	1513	1511	1508	1506	1504	1502	1499	1497	1495
6-7	0-1493	1490	1488	1486	1484	1481	1479	1477	1475	1473
6-8	0-1471	1468	1466	1464	1462	1460	1458	1456	1453	1451
6-9	0-1449	1447	1445	1443	1441	1439	1437	1435	1433	1431
7-0	0-1429	1427	1425	1422	1420	1418	1416	1414	1412	1410
7-1	0-1408	1406	1404	1403	1401	1399	1397	1395	1393	1391
7-2	0-1389	1387	1385	1383	1381	1379	1377	1376	1374	1372
7-3	0-1370	1368	1366	1364	1362	1361	1359	1357	1355	1353
7-4	0-1351	1350	1348	1346	1344	1342	1340	1339	1337	1335
7-5	0-1333	1332	1330	1328	1326	1325	1323	1321	1319	1318
7-6	0-1316	1314	1312	1311	1309	1307	1305	1304	1302	1300
7-7	0-1299	1297	1295	1292	1290	1289	1287	1285	1284	1282
7-8	0-1282	1280	1279	1277	1274	1272	1271	1269	1267	1265
7-9	0-1265	1264	1263	1261	1259	1258	1256	1255	1253	1252
8-0	0-1250	1248	1247	1245	1244	1242	1241	1239	1238	1236
8-1	0-1235	1233	1232	1230	1229	1227	1225	1224	1222	1221
8-2	0-1220	1218	1217	1215	1214	1212	1211	1209	1208	1206
8-3	0-1205	1203	1202	1200	1199	1198	1193	1192	1190	1189
8-4	0-1190	1189	1188	1186	1185	1183	1182	1181	1179	1178
8-5	0-1176	1175	1174	1172	1171	1170	1168	1167	1165	1164
8-6	0-1163	1161	1160	1159	1157	1156	1155	1153	1152	1151
8-7	0-1149	1148	1147	1145	1144	1143	1142	1140	1139	1138
8-8	0-1136	1135	1134	1133	1131	1130	1129	1127	1126	1125
8-9	0-1124	1122	1121	1120	1119	1117	1116	1115	1114	1112
9-0	0-1111	1110	1109	1107	1106	1105	1104	1103	1101	1100
9-1	0-1099	1098	1096	1094	1093	1092	1090	1089	1088	1087
9-2	0-1087	1086	1085	1083	1081	1080	1079	1078	1076	1075
9-3	0-1075	1074	1073	1072	1071	1070	1068	1067	1065	1065
9-4	0-1064	1063	1062	1060	1059	1058	1057	1056	1055	1054
9-5	0-1053	1052	1050	1049	1048	1047	1046	1045	1044	1043
9-6	0-1042	1041	1039	1038	1037	1035	1034	1033	1032	1031
9-7	0-1031	1030	1029	1028	1027	1026	1024	1022	1021	1020
9-8	0-1020	1019	1018	1017	1016	1015	1013	1012	1011	1010
9-9	0-1010	1009	1008	1007	1006	1005	1004	1003	1002	1001

Natural Logarithms

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	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1-0	0-0000	0100	0198	0296	0392	0488	0583	0677	0770	0862	10	19	29	38	48	57	67	76	86
1-1	0-0953	1044	1133	1222	1310	1398	1484	1570	1655	1740	9	17	26	35	44	52	61	70	78
1-2	0-1823	1808	1889	2070	2151	2231	2311	2390	2469	2546	8	16	24	32	40	48	56	64	72
1-3	0-2624	2700	2776	2852	2927	3001	3075	3148	3221	3293	7	15	22	30	37	44	52	59	67
1-4	0-3365	3436	3507	3577	3646	3716	3784	3853	3920	3988	7	14	21	28	35	41	48	55	62
1-5	0-4055	4121	4187	4252	4310	4373	4447	4511	4574	4637	6	13	19	26	32	39	45	52	59
1-6	0-4700	4762	4824	4883	4947	5008	5068	5128	5188	5247	6	12	18	24	30	36	42	48	55
1-7	0-5303	5365	5423	5481	5539	5596	5653	5710	5768	5822	6	11	17	23	29	34	40	46	51
1-8	0-5878	5933	5988	6043	6098	6152	6208	6269	6313	6366	5	11	16	22	27	32	38	43	49
1-9	0-6419	6471	6523	6575	6627	6678	6729	6780	6831	6881	5	10	15	20	26	31	36	41	46
2-0	0-6981	6981	7031	7080	7129	7178	7227	7275	7324	7372	5	10	15	20	24	29	34	39	44
2-1	0-7419	7467	7514	7561	7608	7655	7701	7747	7793	7839	5	9	14	19	23	28	33	37	42
2-2	0-7885	7930	7975	8020	8065	8109	8154	8198	8242	8286	4	9	13	18	22	27	31	36	40
2-3	0-8329	8372	8416	8459	8502	8544	8587	8629	8671	8713	4	9	13	17	21	26	30	34	38
2-4	0-8755	8794	8838	8879	8920	8961	9002	9042	9083	9123	4	8	12	16	20	24	29	33	37
2-5	0-9163	9203	9243	9282	9322	9361	9400	9439	9478	9517	4	8	12	16	20	24	27	31	35
2-6	0-9555	9594	9632	9670	9708	9746	9783	9821	9858	9895	4	8	11	15	19	23	26	30	34
2-7	0-9933	9969	0006	0043	0080	0116	0152	0188	0225	0260	4	7	11	15	18	22	25	29	33
2-8	1-0289	0332	0367	0403	0438	0473	0508	0543	0578	0613	4	7	11	14	18	21	25	28	32
2-9	1-0647	0682	0716	0750	0784	0818	0852	0886	0919	0953	3	7	10	14	17	20	24	27	31
3-0	1-0886	1010	1053	1088	1119	1151	1184	1217	1249	1282	3	7	10	13	16	20	23	26	30
3-1	1-1314	1346	1378	1410	1442	1474	1503	1537	1569	1600	3	6	10	13	16	19	22	25	29
3-2	1-1632	1663	1694	1725	1756	1787	1817	1848	1878	1909	3	6	9	12	15	18	22	25	28
3-3	1-1939	1939	2004	2030	2080	2091	2119	2149	2179	2208	3	6	9	12	15	18	21	24	27
3-4	1-2238	2267	2298	2326	2355	2384	2413	2442	2470	2499	3	6	9	12	15	17	20	23	26
3-5	1-2528	2556	2585	2613	2641	2669	2698	2726	2754	2782	3	6	9	11	14	17	20	23	25
3-6	1-2809	2837	2865	2892	2920	2947	2975	3002	3029	3056	3	5	8	11	14	16	19	22	25
3-7	1-3083	3110	3137	3164	3191	3218	3244	3271	3297	3324	3	5	8	11	13	16	19	21	24
3-8	1-3350	3376	3403	3432	3455	3481	3507	3535	3568	3594	3	5	8	10	13	16	18	21	23
3-9	1-3610	3635	3661	3686	3712	3737	3762	3788	3813	3838	3	5	8	10	13	15	18	20	23
4-0	1-3963	3983	3913	3938	3962	3987	4012	4036	4061	4085	2	5	7	10	12	15	17	20	22
4-1	1-4110	4134	4159	4183	4207	4231	4255	4279	4303	4327	2	5	7	10	12	14	17	19	22
4-2	1-4351	4375	4398	4422	4446	4469	4493	4516	4540	4563	2	5	7	9	12	14	16	19	21
4-3	1-4586	4604	4633	4656	4679	4702	4725	4748	4770	4793	2	5	7	9	12	14	16	18	21
4-4	1-4816	4839	4861	4884	4907	4929	4953	4974	4998	5019	2	5	7	9	11	14	16	18	20
4-5	1-5041	5063	5085	5107	5129	5151	5173	5195	5217	5239	2	4	7	9	11	13	15	18	20
4-6	1-5261	5222	5304	5326	5347	5369	5390	5412	5433	5454	2	4	6	9	11	13	15	17	19
4-7	1-5470	5497	5518	5539	5560	5581	5602	5623	5644	5665	2	4	6	8	11	13	15	17	19
4-8	1-5688	5707	5728	5748	5769	5790	5810	5831	5851	5872	2	4	6	8	10	12	14	16	19
4-9	1-5892	5913	5933	5953	5974	5994	6014	6034	6054	6074	2	4	6	8	10	12	14	16	18
5-0	1-6094	6114	6134	6154	6174	6194	6214	6233	6253	6273	2	4	6	8	10	12	14	16	18
5-1	1-6292	6312	6332	6351	6371	6390	6409	6429	6448	6467	2	4	6	8	10	12	14	16	18
5-2	1-6497	6508	6525	6544	6563	6582	6601	6620	6639	6658	2	4	6	8	10	11	13	15	17
5-3	1-6677	6686	6715	6734	6752	6771	6790	6808	6827	6845	2	4	6	7	9	11	13	15	17
5-4	1-6864	6882	6901	6919	6939	6956	6974	6993	7011	7029	2	4	5	7	9	11	13	15	17

NATURAL LOGARITHMS OF 10ⁿ

n	1	2	3	4	5	6	7	8	9
log _e 10 ⁿ	2.3026	4.6052	6.9078	9.2103	11.5129	13.8155	16.1181	18.4207	20.7233

E.g. log_e 5847 × 10³ = log_e(5.847 × 10³) = 1.7639 + 4.6052 = 6.3711.

Natural Logarithms

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	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
5-5	1-7047	7066	7084	7102	7120	7138	7156	7174	7192	7210	2	4	5	7	9	11	13	14	16
5-6	1-7228	7246	7263	7281	7299	7317	7334	7352	7370	7387	2	4	5	7	9	11	12	14	16
5-7	1-7405	7422	7440	7457	7475	7492	7509	7527	7544	7561	2	3	5	7	9	10	12	14	16
5-8	1-7579	7596	7613	7630	7647	7664	7681	7699	7716	7733	2	3	5	7	9	10	12	14	15
5-9	1-7750	7766	7783	7800	7817	7834	7851	7867	7884	7901	2	3	5	7	9	10	12	13	15
6-0	1-7918	7934	7951	7967	7984	8001	8017	8034	8050	8066	2	3	5	7	9	10	12	13	15
6-1	1-8083	8099	8116	8132	8148	8165	8181	8197	8213	8229	2	3	5	6	8	9	11	12	14
6-2	1-8245	8262	8278	8294	8310	8326	8342	8358	8374	8390	2	3	5	6	8	9	10	11	13
6-3	1-8405	8421	8437	8453	8469	8485	8500	8516	8532	8547	2	3	5	6	8	9	11	13	14
6-4	1-8563	8579	8594	8610	8626	8641	8656	8672	8687	8703	2	3	5	6	8	9	11	12	14
6-5	1-8718	8733	8749	8764	8780	8795	8810	8825	8840	8856	2	3	5	6	8	9	11	12	14
6-6	1-8871	8886	8901	8916	8931	8946	8961	8976	8991	9006	2	3	5	6	8	9	11	12	14
6-7	1-9021	9036	9051	9066	9081	9096	9110	9125	9140	9155	1	2	4	5	6	7	9	10	12
6-8	1-9169	9184	9199	9213	9228	9242	9257	9272	9286	9301	1	2	4	5	6	7	9	10	12
7-0	1-9315	9330	9344	9359	9373	9387	9402	9416	9430	9445	1	2	4	5	6	7	9	10	13
7-1	1-9601	9615	9629	9643	9657	9671	9685	9699	9713	9727	1	2	4	5	6	7	8	9	11
7-2	1-9741	9755	9769	9782	9796	9810	9824	9838	9851	9865	1	2	3	4	5	6	7	8	10
7-3	1-9879	9892	9906	9920	9933	9947	9961	9974	9988	9991	1	2	3	4	5	6	7	8	10
7-4	2-0015	0028	0042	0055	0069	0082	0096	0102	0118	0133	1	2	3	4	5	6	7	8	10
7-5	2-0149	0162	0176	0190	0202	0215	0229	0242	0255	0268	1	2	3	4	5	6	7	8	11
7-6	2-0282	0295	0308	0321	0334	0347	0360	0373	0386	0399	1	2	3</						

Exponential and Hyperbolic Functions

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x	e^x	e^{-x}	θ° (gd x)	$\cosh x$ (sec θ)	$\sinh x$ (tan θ)	$\tanh x$ (sin θ)	$\log \cosh x$	$\log \sinh x$
0.1	1.1052	0.9046	5.720	1.0050	0.1002	0.0997	0.0022	1.0007
0.2	1.2214	0.8187	11.384	1.0201	0.2013	0.1974	0.0038	1.3039
0.3	1.3499	0.7408	16.937	1.0453	0.3045	0.2913	0.0193	1.8436
0.4	1.4916	0.6703	22.331	1.0811	0.4108	0.3799	0.0339	1.6136
0.5	1.6497	0.6065	27.524	1.1276	0.5211	0.4621	0.0522	1.7168
0.6	1.8221	0.5488	32.483	1.1855	0.6387	0.5370	0.0739	1.8093
0.7	2.0138	0.4966	37.183	1.2552	0.7596	0.6044	0.0987	1.6800
0.8	2.2255	0.4493	41.608	1.3374	0.8881	0.6840	0.1263	1.9485
0.9	2.4588	0.4068	45.750	1.4331	1.0265	0.7163	0.1563	0.0114
1.0	2.7183	0.3679	49.605	1.5431	1.1752	0.7616	0.1884	0.0701
1.1	3.0042	0.3329	53.178	1.6685	1.3356	0.8005	0.2223	0.1257
1.2	3.3201	0.3012	56.476	1.8107	1.5085	0.8337	0.2578	0.1788
1.3	3.6693	0.2725	59.511	1.9709	1.6984	0.8617	0.2847	0.2300
1.4	4.0552	0.2466	62.295	2.1509	1.9043	0.8854	0.3326	0.2797
1.5	4.4817	0.2231	64.843	2.3524	2.1203	0.9051	0.3715	0.3282
1.6	4.9530	0.2019	67.171	2.5775	2.3756	0.9217	0.4112	0.3758
1.7	5.4739	0.1827	69.294	2.8283	2.6456	0.9354	0.4515	0.4225
1.8	6.0488	0.1653	71.228	3.1075	3.0422	0.9468	0.4924	0.4687
1.9	6.6859	0.1486	72.987	3.4177	3.2682	0.9562	0.5337	0.5143
2.0	7.3891	0.1353	74.584	3.7632	3.6269	0.9640	0.5754	0.5595
2.1	8.1682	0.1225	76.037	4.1443	4.0219	0.9705	0.6175	0.6044
2.2	9.0250	0.1100	77.354	4.5679	4.4571	0.9757	0.6597	0.6491
2.3	9.9742	0.1003	78.549	5.0372	4.9370	0.9801	0.7022	0.6935
2.4	11.023	0.0907	79.633	5.5569	5.4662	0.9837	0.7448	0.7377
2.5	12.183	0.0821	80.615	6.1323	6.0502	0.9868	0.7876	0.7818
2.6	13.464	0.0743	81.513	6.7690	6.6947	0.9890	0.8305	0.8257
2.7	14.860	0.0672	82.310	7.4735	7.4083	0.9910	0.8735	0.8698
2.8	16.445	0.0608	83.040	8.2527	8.1919	0.9926	0.9168	0.9134
2.9	18.174	0.0550	83.707	9.1146	9.0586	0.9940	0.9587	0.9571
3.0	20.086	0.0498	84.301	10.088	10.018	0.9951	1.0020	1.0008
3.1	22.198	0.0450	84.841	11.121	11.076	0.9959	1.0482	1.0444
3.2	24.533	0.0408	85.336	12.287	12.246	0.9967	1.0894	1.0880
3.3	27.113	0.0369	85.775	13.575	13.538	0.9973	1.1327	1.1316
3.4	29.984	0.0334	86.177	14.999	14.985	0.9978	1.1761	1.1751
3.5	33.115	0.0302	86.541	16.573	16.543	0.9982	1.2194	1.2186
3.6	38.598	0.0273	86.870	18.313	18.285	0.9985	1.2628	1.2621
3.7	40.447	0.0247	87.163	20.236	20.211	0.9988	1.3061	1.3056
3.8	44.701	0.0224	87.437	22.362	22.339	0.9990	1.3495	1.3491
3.9	49.402	0.0202	87.681	24.711	24.691	0.9992	1.3929	1.3925
4.0	54.598	0.0183	87.903	27.303	27.290	0.9993	1.4363	1.4360
4.1	60.340	0.0166	88.104	30.178	30.162	0.9995	1.4797	1.4795
4.2	66.686	0.0150	88.281	33.351	33.336	0.9996	1.5231	1.5229
4.3	73.700	0.0138	88.447	36.857	36.843	0.9998	1.5665	1.5664
4.4	81.451	0.0123	88.591	40.732	40.719	0.9997	1.6099	1.6098
4.5	90.017	0.0111	88.728	45.014	45.003	0.9997	1.6533	1.6532
4.6	99.484	0.0101	88.849	49.747	49.737	0.9998	1.6968	1.6967
4.7	109.95	0.0091	88.957	54.978	54.969	0.9998	1.7402	1.7401
4.8	121.51	0.0082	89.055	60.759	60.751	0.9999	1.7836	1.7836
4.9	134.29	0.0074	89.146	67.149	67.141	0.9999	1.8270	1.8270
5.0	148.41	0.0067	89.227	74.210	74.203	0.9999	1.8705	1.8704

Mathematical Constants and Formulae

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Constants

- e = Base of natural logarithms ≈ 2.71828
 $\log_{10} e \approx 0.434294$ $\log_{10} 10 \approx 2.30259$
 $\log_{10} N \approx \log_{10} N \times 0.4343$ $\log_e N \approx \log_{10} N \times 2.3026$
 1 radian $\approx 57^\circ 29' 58'' \approx 57^\circ 17' 45''$ $\pi \approx 3.14159265$
 $\log_{10} \pi \approx 0.49715$ $\frac{1}{\pi} \approx 0.31831$ $\frac{\pi}{180} \approx 0.01745$ $\pi^2 \approx 9.8696$

Algebra

- $\log_a x = y \Leftrightarrow x = a^y$ $\log_a p = \log_a r \log_a p$
 Sum of first n terms of the series $a, a+d, a+2d, \dots$
 $S_n = \frac{1}{2}n[2a + (n-1)d] = n \times (\text{average of first and last terms})$

$$\sum_{r=1}^n r = \frac{1}{2}n(n+1) \quad \sum_{r=1}^n r^2 = \frac{1}{3}n(n+1)(2n+1)$$

$$\sum_{r=1}^n r^3 = \frac{1}{4}n^2(n+1)^2 \quad \sum_{r=1}^{n-1} a^r = \frac{1-a^n}{1-a}$$

- If $f(x) = ax^2 + bx + c$, roots α, β of $f(x) = 0$
 given by $\frac{(-b \pm \sqrt{b^2 - 4ac})}{2a}$ Also $\alpha + \beta = -\frac{b}{a}$, $\alpha\beta = \frac{c}{a}$

$f(x) > 0$ all real $x \Leftrightarrow a > 0, c > 0, 4ac > b^2$

Remainder when polynomial $P(x)$ divided by $(x-a)$ is $P(a)$

Number of combinations of n objects taken r at a time

$$nC_r \text{ or } \binom{n}{r} = \frac{n!}{(n-r)!r!} \text{ where } n! = n(n-1)(n-2) \dots 3.2.1$$

Complex number $Z = x+iy = r(\cos\theta + i \sin\theta) = re^{i\theta}$

$$\text{Mod } Z = |Z| = r = \sqrt{x^2 + y^2} \quad \text{Arg } Z = \theta + 2\pi n$$

Where p is taken such that $-\pi < \text{Arg } Z \leq \pi$

$$Z_1 Z_2 = r_1 e^{i\theta_1} r_2 e^{i\theta_2} = r_1 r_2 e^{i(\theta_1 + \theta_2)} \quad Z^n = r^n e^{in\theta}$$

Vectors

- If \mathbf{x} has components (x_1, x_2, x_3) and \mathbf{y} has components (y_1, y_2, y_3)
 $\mathbf{x} \cdot \mathbf{y} = x_1 y_1 + x_2 y_2 + x_3 y_3$
 and $\mathbf{x} \times \mathbf{y}$ has components $(x_2 y_3 - x_3 y_2, x_3 y_1 - x_1 y_3, x_1 y_2 - x_2 y_1)$

$$\mathbf{x} \times \mathbf{y}, \mathbf{z} = \begin{vmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ z_1 & z_2 & z_3 \end{vmatrix} \quad \mathbf{x} \times (\mathbf{y} \times \mathbf{z}) = (\mathbf{x} \cdot \mathbf{z})\mathbf{y} - (\mathbf{x} \cdot \mathbf{y})\mathbf{z}$$

$$\mathbf{v} = i \frac{\partial}{\partial x} + j \frac{\partial}{\partial y} + k \frac{\partial}{\partial z}$$

$$\text{Grad } \varphi = \nabla \varphi \quad \text{Div } \mathbf{a} = \nabla \cdot \mathbf{a} \quad \text{Curl } \mathbf{a} = \nabla \times \mathbf{a}$$

$$\nabla^2 \varphi = \frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2}$$

and in spherical polar coordinates r, θ, ψ

$$\nabla^2 \varphi = \frac{\partial^2 \varphi}{\partial r^2} + \frac{2}{r} \frac{\partial \varphi}{\partial r} + \frac{1}{r^2} \frac{\partial^2 \varphi}{\partial \theta^2} + \cot \theta \frac{\partial \varphi}{\partial \theta} + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 \varphi}{\partial \psi^2}$$

Expansions and Approximations

Taylor's expansion: $f(a+x) = f(a) + xf'(a) + \frac{x^2}{2!}f''(a) + \frac{x^3}{3!}f'''(a) + \dots$

or (Maclaurin's form): $f(x) = f(0) + xf'(0) + \frac{x^2}{2!}f''(0) + \frac{x^3}{3!}f'''(0) + \dots$

Expansions (*valid if $|x| < 1$, the rest valid for all x)

$$\sin x = \frac{x}{1!} - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots$$

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

$$\sinh x = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} + \dots$$

$$\cosh x = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \frac{x^6}{6!} + \dots$$

$$^*\log(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \dots$$

$$^*(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \dots + \binom{n}{r}x^r + \dots$$

Newton-Raphson iterative formula for root of $f(x) = 0$: $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$

Kinematics and Centres of Gravity

Components of acceleration in polar coordinates

$$\text{Radial } \dots a_r = \ddot{r} - r\dot{\theta}^2 \quad \text{Tangential } \dots a_t = \frac{1}{r} \frac{d}{dt}(r^2\dot{\theta})$$

Distance of centre of gravity from the centre (d)

$$(a) \text{ Hemisphere (radius } r) \quad d = \frac{3r}{8}$$

$$(b) \text{ Hemispherical shell} \quad d = \frac{r}{2}$$

$$(c) \text{ Sector of circle (angle } 2\theta) \quad d = \frac{(2r \sin \theta)}{3\theta}$$

$$(d) \text{ Arc of circle} \quad d = \frac{(r \sin \theta)}{\theta}$$

$$(e) \text{ Cone (height } h) \quad d = \frac{h}{4} \text{ (from centre of base)}$$

Analysis

(a) List of derivatives

y	$\frac{dy}{dx}$	y	$\frac{dy}{dx}$
$\sin x$	$\cos x$	$\cos x$	$-\sin x$
$\tan x$	$\sec^2 x$	$\cot x$	$-\operatorname{cosec}^2 x$
$\sec x$	$\sec x \tan x$	$\operatorname{cosec} x$	$-\operatorname{cosec} x \cot x$

(b) List of integrals

$F'(x) = f(x)$	$F(x) = \int f(x)dx$	$F'(x) = f(x)$	$F(x) = \int f(x)dx$
x^a	$\frac{x^{a+1}}{a+1} \quad a \neq -1$	$\frac{1}{a^2+x^2}$	$\frac{1}{a} \tan^{-1} \frac{x}{a}$
$\frac{1}{x}$	$\log x $	$x \sqrt{x^2-a^2}$	$\frac{1}{a} \sec^{-1} \frac{x}{a}$
e^x	e^x	$\frac{1}{(a^2-x^2)}$	$\frac{1}{a} \tanh^{-1} \frac{x}{a}$
a^x	$\frac{a^x}{\log a}$		$= \frac{1}{2a} \log \left(\frac{a+x}{a-x} \right)$
$\frac{1}{\sqrt{a^2-x^2}}$	$\sin^{-1} \frac{x}{a}$	$\tan x$	$\log \sec x $
$\frac{1}{\sqrt{x^2+a^2}}$	$\sinh^{-1} \frac{x}{a}$	$\sec x$	$\log \sec x + \tan x $
	$= \log \left(\frac{x}{a} + \sqrt{\frac{x^2}{a^2} + 1} \right)$	$\operatorname{cosec} x$	$= \log \left \tan \left(\frac{x}{2} + \frac{\pi}{4} \right) \right $
$\pm \frac{1}{\sqrt{x^2-a^2}}$	$\cosh^{-1} \frac{x}{a}$	$e^{ax} \sin(bx+c)$	$\frac{e^{ax}}{a^2+b^2} \left[a \sin(bx+c) \right.$
		$= \log \left(\frac{x}{a} \pm \sqrt{\frac{x^2}{a^2} - 1} \right)$	$\left. - b \cos(bx+c) \right]$

Simpson's rule $\int_a^b f(x)dx \approx \frac{h}{3}(y_0 + 4y_1 + y_2)$ where $h = \frac{1}{3}(b-a)$

$$(uv)' = u'v + uv', \left(\frac{u}{v} \right)' = \frac{u'v - uv'}{v^2}$$

$$\int u v' dx = u v - \int u' v dx$$

$$\int_0^\pi \sin^m x \cos^n x dx = \frac{(n-1)(n-3) \dots (m-1)(m-3)}{(m+n)(m+n-2)} \dots \lambda$$

where $\lambda = \frac{\pi}{2}$ if m, n both even, and 1 otherwise

$$\text{Radius of curvature } \rho = \frac{ds}{dy} = \frac{\left[1 + \left(\frac{dy}{dx} \right)^2 \right]^{3/2}}{\frac{d^2y}{dx^2}} = \frac{(x^2 + y^2)^{3/2}}{xy - \bar{y}\bar{x}}$$

Mensuration

Area of triangle, (sides a, b, c): $\Delta = \frac{1}{2}bc \sin A$

or $\sqrt{s(s-a)(s-b)(s-c)}$ where $2s = a+b+c$

Circle (radius r): Perimeter = $2\pi r$ Area = πr^2

Ellipse (axes $2a, 2b$): Perimeter $\approx 2\pi \sqrt{\frac{a^2+b^2}{2}}$ Area = πab

Cylinder (radius r , height h): Area = $2\pi rh + 2\pi r^2$, Volume = $\pi r^2 h$

Area of curved surface of cone = πrl , where l = slant height

Volume of cone or pyramid = $\frac{1}{3}Ah$, where A = base area, h = height

Sphere (radius r): Area $4\pi r^2$, Volume $\frac{4}{3}\pi r^3$

Area cut off on sphere by parallel planes h apart = $2\pi rh$

Trigonometry

$$(a) \sin(\theta \pm \varphi) = \sin \theta \cos \varphi \pm \cos \theta \sin \varphi$$

$$\cos(\theta \pm \varphi) = \cos \theta \cos \varphi \mp \sin \theta \sin \varphi$$

$$\tan(\theta \pm \varphi) = \frac{\tan \theta \pm \tan \varphi}{1 \mp \tan \theta \tan \varphi}$$

$$\sin 2\theta = 2 \sin \theta \cos \theta$$

$$\cos 2\theta = \cos^2 \theta - \sin^2 \theta = 2 \cos^2 \theta - 1 = 1 - 2 \sin^2 \theta$$

$$\sin 3\theta = 3 \sin \theta - 4 \sin^3 \theta, \cos 3\theta = 4 \cos^3 \theta - 3 \cos \theta$$

$$\sin A + \sin B = 2 \sin \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B)$$

$$\sin A - \sin B = 2 \cos \frac{1}{2}(A+B) \sin \frac{1}{2}(A-B)$$

$$\cos A + \cos B = 2 \cos \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B)$$

$$\cos A - \cos B = -2 \sin \frac{1}{2}(A+B) \sin \frac{1}{2}(A-B)$$

$$\text{If } \tan \frac{1}{2}x = t, \sin x = \frac{2t}{1+t^2}, \cos x = \frac{1-t^2}{1+t^2}$$

$$\tan x = \frac{2t}{1-t^2}, dx = \frac{2}{1+t^2} dt$$

$$(b) \text{ In any triangle: } \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R \text{ (sine rule)}$$

$$a^2 = b^2 + c^2 - 2bc \cos A \text{ (cosine rule)}$$

$$\sin \frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}}, \cos \frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}}$$

Radius of circumcircle, $R = abc/4\Delta$ (where Δ = area of triangle)

Radius of inscribed circle, $r = \frac{s}{s}$

Geometry

The polar form for a conic with origin at the focus is

$l = r(1+e \cos \theta)$ For ellipse/hyperbola $e \leq 1$

and foci are $(\pm ae, 0)$, directrices $x = \pm \frac{a}{e}$, where $b^2 = a^2[1-e^2]$

Solid angle: The solid angle of a cone is given by the area intercepted by the cone on the surface of a sphere of unit radius, with centre at the vertex.

When making measurements of a physical quantity, the final result is expressed as a number followed by the unit. The number expresses the ratio of the measured quantity to some fixed standard and the unit is the name or symbol for the standard. Over the years, a large number of standards have been defined for physical measurement and many systems of units have evolved. Recently, there has been an attempt to simplify the language of science by the adoption of a system of units, the Système International d'Unités, which is intended to be used universally. This system of units, SI, was the outcome of a resolution of the 9th General Conference of Weights and Measures (CGPM) in 1948, which instructed an international committee to 'study the establishment of a complete set of rules for units of measurement.' The constants in this book are given in SI except where stated otherwise.

SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units.

Base Units in SI: There are seven base units:

- (i) the metre, the standard of length,
- (ii) the kilogram, the standard of mass,
- (iii) the second, the standard of time,
- (iv) the ampere, the standard of electric current,
- (v) the kelvin, the standard of temperature,
- (vi) the candela, the standard of luminous intensity, and
- (vii) the mole, the standard of amount of substance.

Derived Units: Derived units can be formed by combining base units. Thus the unit of force can be produced by combining the first three base units. Often derived units are given names, e.g. the unit of force is the newton.

Supplementary Units: Two supplementary units are at present defined, the radian and the steradian, which are the units for plane and solid angles respectively.

SI Prefixes and Multiplication Factors: To obtain multiples and submultiples of units, standard prefixes are used as shown below:

Multiplication factor	Prefix	Symbol
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera	T
$1\ 000\ 000\ 000 = 10^9$	giga	G
$1\ 000\ 000 = 10^6$	mega	M
$1\ 000 = 10^3$	kilo	k
$100 = 10^2$	hecto	h
$10 = 10^1$	deca	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	μ
$0.000\ 000\ 001 = 10^{-9}$	nano	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	p
$0.000\ 000\ 000\ 000\ 001 = 10^{-15}$	femto	f
$0.000\ 000\ 000\ 000\ 000\ 001 = 10^{-18}$	atto	a

It should be noted that masses are still expressed as multiples of the gram, although the base unit is the kilogram. Thus 10^{-6} kg should be written as 1 mg.

Other systems of units. Some other systems of units are still in common use. Thus for mechanical measurements, the British or fps system is still largely used, while for electrical measurements, the electrostatic and electromagnetic cgs systems are by no means obsolete. In the pages which follow, these systems of units are discussed and tables are included to help in conversion from one system to another.

2 The Fundamental Mechanical Units

(a) SI UNITS

In any system of measurement in mechanics, three fundamental units are required. These are the units of length, mass and time. The base units as used in SI are the metre, kilogram and second.

The metre (m)

This is defined as 1 650 763.73 of the wavelength, in vacuo of the orange light emitted by ^{86}Kr in the transition 2p_{10} to 5d_5 .

The kilogram (kg)

This is defined as the mass of a platinum-iridium cylinder kept at Sèvres. Originally intended to be the mass of a cubic decimetre of water at its maximum density, the cylinder was subsequently found to be 28 parts per million too large. The cylinder was then taken as an arbitrary standard of mass, while the volume of water which had the same mass (at maximum density) was defined to be one litre (l). Thus 1 litre = 1000.028 cm³. The 1964 General Conference on Weights and Measures redefined the litre to be a cubic decimetre, but recommended that this unit should not be used in work of high precision.

The second (s)

This is the time taken by 9 192 631 770 cycles of the radiation from the hyperfine transition in caesium when unperturbed by external fields. Alternatively the ephemeris second is defined as 1/31 556 925.974 7 of the tropical year for 1900.

Derived units of length, mass and time

Through common usage, certain multiples and submultiples of the three fundamental units have been given names. A list of the more common ones is given below as they have been in frequent use. None of them is a recognised SI unit.

Length and area	Mass	Time
Micron (μm) = 10^{-6} m	Tonne (t) = 10^6 g	Minute (min) = 60 s
Angstrom (\AA) = 10^{-10} m	= 1000 kg	Hour (h) = 3 600 s
Fermi (fm) = 10^{-15} m		Day (d) = 86 400 s
Are (a) = 100 m ²		Year (a) $\approx 3.1557 \times 10^7$ s
Barn (b) = 10^{-28} m ²		

SUPPLEMENTARY UNITS

The radian (rad) is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.

The steradian (sr) is the solid angle which, having its vertex in the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

Other units of angular measure are:

The degree ($^\circ$) is a unit of angle equal to $(\pi/180)$ rad.

The minute of arc ($'$) is $(1/60)$ degree and thus is equal to $(\pi/10\ 800)$ rad.

The second of arc ($''$) is $(1/60)$ minute and thus is equal to $(\pi/648\ 000)$ rad.

(b) THE CGS SYSTEM

A lot of early scientific work was done using the centimetre, gram and second as the base units in mechanics. Derived units in the cgs system were given names and some of them are still used. The table below lists the more common of the named derived units in SI and cgs with the conversion factors. The International Union of Pure and Applied Physics has recommended that certain symbols be used in scientific work and these are also included in the first column.

DERIVED UNITS IN SI AND CGS

Quantity and recommended symbol	Dimensions	SI unit	cgs unit	Ratio cgs/SI units
Mass m	M	kilogram (kg)	gram (g)	10^{-3}
Length l	L	metre (m)	centimetre (cm)	10^{-2}
Time t	T	second (s)	second (s)	1
Area A, S	L^2	m^2	cm^2	10^{-4}
Volume V	L^3	m^3	cm^3	10^{-6}
Density ρ	ML^{-3}	kg m^{-3}	g cm^{-3}	10^3
Velocity u, v	LT^{-1}	m s^{-1}	cm s^{-1}	10^{-2}
Acceleration a	LT^{-2}	m s^{-2}	gal	10^{-2}
Momentum p	MLT^{-1}	kg m s^{-1}	g cm s^{-1}	10^{-5}
Moment of Inertia I, J	ML^2	kg m^2	g cm^2	10^{-7}
Angular Momentum L	ML^2T^{-1}	$\text{kg m}^2\text{s}^{-1}$	$\text{g cm}^2\text{s}^{-1}$	10^{-7}
Force F	MLT^{-2}	newton (N)	dyn (dyn)	10^{-5}
Energy or Work E, W	ML^2T^{-2}	joule (J)	erg	10^{-7}
Power P	ML^2T^{-3}	watt (W)	erg s^{-1}	10^{-7}
Pressure or Stress p	$\text{ML}^{-1}\text{T}^{-2}$	pascal (Pa)	dyn cm^{-2}	10^{-4}
Surface Tension γ	MT^{-2}	N m^{-1}	dyn cm^{-1}	10^{-4}
Viscosity η	$\text{ML}^{-1}\text{T}^{-1}$	$\text{kg m}^{-1}\text{s}^{-1}$	poise	10^{-1}
Frequency v, f	T^{-1}	hertz (Hz)	s^{-1}	10^{-1}

NOTE: The ratio in the final column is that of the *actual units*. Thus the SI unit of pressure, the pascal, is 10 times larger than the cgs unit, the dyne cm⁻². This means that a pressure of 1 pascal is the same as a pressure of 10 dyne cm⁻².

(c) THE BRITISH OR fps SYSTEM

In this system of units, the standards of length and mass are the *foot* and the *pound*. The unit of time is the *second* which is defined as in the metric system.

The foot (ft)

The foot is one-third of the Imperial Standard yard which is now defined to be 0·9144 metre exactly. Thus the foot is defined as 0·3048 metre exactly.

The pound (lb)

This is now defined to be 0·453 592 37 kilogram exactly.

The gallon (gal)

This unit of volume is also defined in the British system. It is the volume occupied by exactly 10 pounds of water of density 0·988 859 gram per millilitre weighed in air of density 0·001 217 gram per millilitre against weights of density 8·136 grams per millilitre.

SECONDARY UNITS IN THE BRITISH SYSTEM

The following list shows the most common secondary units in the British system.

Units of Length

12 inches	= 1 foot (ft)
3 feet	= 1 yard (yd)
22 yards	= 1 chain
10 chains	= 1 furlong
8 furlongs or 1760 yards	= 1 mile (mi)
6080 feet	= 1 UK nautical mile*
6 feet	= 1 fathom

Units of Area

4840 square yards	= 1 acre
640 acres	= 1 square mile

Units of Volume

20 fluid ounces	= 1 pint
(fl. oz)	
2 pints (pt)	= 1 quart
4 quarts (qt)	= 1 gallon

Units of Mass

16 ounces (oz)	= 1 pound (lb)
14 pounds (lb)	= 1 stone
28 pounds	= 1 quarter
4 quarters or 112 pounds	= 1 hundredweight
20 hundredweight (cwt) or 2240 lb	= 1 ton

*The Nautical mile is the average distance on the earth's surface subtended by one minute of latitude. The UK nautical mile is 6080 ft but the International nautical mile, which is used by the Admiralty and most other nations, measures 1852 m.

CONVERSION FACTORS BETWEEN SI AND fps UNITS

fps unit	SI unit	Reciprocal
length 1 inch (in)	$= 2.54 \times 10^{-2}$ m	39-370 079
1 foot (ft)	$= 0.3048$ m	3-280 839
1 yard (yd)	$= 0.9144$ m	1-093 613
1 fathom	$= 1.828$ m	0-546 806
1 chain	$= 20.116$ 8 m	4-970 970 $\times 10^{-2}$
1 furlong	$= 2.011$ 68 $\times 10^3$ m	4-970 970 $\times 10^{-3}$
1 mile (mi)	$= 1.609$ 344 $\times 10^3$ m	6-213 712 $\times 10^{-4}$
Area 1 in ²	$= 6.451$ 6 $\times 10^{-4}$ m ²	1-550 003 $\times 10^3$
1 ft ²	$= 9.290$ 304 $\times 10^{-2}$ m ²	10-763 910
1 yd ²	$= 0.836$ 127 m ²	1-195 990
1 mi ²	$= 2.589$ 988 $\times 10^6$ m ²	3-861 022 $\times 10^{-7}$
1 acre	$= 4.046$ 856 $\times 10^3$ m ²	2-471 054 $\times 10^{-4}$
Volume 1 in ³	$= 1.638$ 706 $\times 10^{-5}$ m ³	6-102 374 $\times 10^4$
1 ft ³	$= 2.831$ 685 $\times 10^{-2}$ m ³	35-314 67
1 yd ³	$= 0.764$ 555 m ³	1-307 950
1 fluid ounce (fl oz)	$= 2.841$ 306 $\times 10^{-5}$ m ³	3-519 508 $\times 10^4$
1 pint (pt)	$= 5.682$ 613 $\times 10^{-4}$ m ³	1-759 754 $\times 10^3$
1 quart (qt)	$= 1.136$ 523 $\times 10^{-3}$ m ³	8-798 770 $\times 10^2$
1 gallon (gal)	$= 4.546$ 09 $\times 10^{-3}$ m ³	2-199 692 $\times 10^2$
1 bushel (bu)	$= 0.036$ 369 m ³	27-495 944
1 gallon USA (= 231 in ³)	$= 3.785$ 412 $\times 10^{-3}$ m ³	2-641 721 $\times 10^2$
Mass 1 ounce (oz)	$= 2.834$ 952 $\times 10^{-2}$ kg	35-273 962
1 pound (lb)	$= 0.453$ 592 37 kg	2-204 623
1 stone	$= 6.350$ 293 kg	0-157 473
1 quarter	$= 12.700$ 586 kg	7-873 652 $\times 10^{-2}$
1 hundredweight (cwt)	$= 50.802$ 345 kg	1-968 413 $\times 10^{-2}$
1 ton	$= 1.016$ 047 $\times 10^3$ kg	9-842 065 $\times 10^{-6}$
Density 1 lb ft ⁻³	$= 16.018$ 463 kg m ⁻³	6-242 796 $\times 10^{-2}$
Speed 1 in s ⁻¹	$= 2.54 \times 10^{-2}$ m s ⁻¹	39-370 079
1 ft s ⁻¹	$= 0.3048$ m s ⁻¹	3-280 839
1 mi h ⁻¹	$= 0.447$ 04 m s ⁻¹	2-236 936
Force 1 poundal (pdL)	$= 0.138$ 255 N	7-233 011
1 lbf ('e. the wt of 1 lb mass)	$= 4.448$ 222 N	0-224 809
Pressure 1 lbf in ⁻² (p.s.i.)	$= 6.894$ 757 $\times 10^3$ Pa	1-450 377 $\times 10^{-6}$
Energy 1 ft pdl	$= 4.214$ 011 $\times 10^{-2}$ J	23-730 360
1 ft lbf	$= 1.355$ 817 J	0-737 562
1 Btu	$= 1.055$ 06 $\times 10^3$ J	9-478 134 $\times 10^{-4}$
1 therm	$= 1.055$ 06 $\times 10^8$ J	9-478 134 $\times 10^{-5}$
Power 1 horse power (hp)	$= 7.457$ 00 $\times 10^2$ W	1-341 000 $\times 10^{-2}$
Standard atmosphere	14.695 916 lbf in ⁻² = 1.013 29 $\times 10^5$ Pa	
Standard acceleration of gravity	32.174 05 ft s ⁻² = 9.806 55 m s ⁻²	

When units were first required for the measurement of electrical quantities it was natural to define them in terms of the three fundamental units, centimetre, gram and second, which were already commonly used in mechanics. Electrical phenomena are related to mechanical phenomena by two effects: (a) the force between static electric charges (Coulomb's law) and (b) the force between electric currents (Ampere's law). Correspondingly, two distinct systems of cgs electrical units were introduced: the electrostatic and electromagnetic systems.

Neither of these systems has units of convenient size in practical applications. Consequently, a practical set of electrical units, defined as decimal multiples of the electromagnetic units was established by various International Congresses of Electricians meeting between 1881 and 1889. The first two units defined were the ohm (10^9 emu), chosen to be similar to the Siemens unit of resistance, and the volt (10^8 emu), chosen to be similar to the emf of the Daniell cell. From these, six other units, the ampere, coulomb, joule, watt, henry and farad were derived. These practical units were not made into a complete system, since no magnetic units were defined, the unmodified magnetic units of the electromagnetic system (e.g. oersted and gauss) being used in practical applications.

In 1901, Giorgi showed that if the metre, kilogram, and second were used as fundamental units instead of the centimetre, gram and second, a single, consistent and comprehensive system of electrical and magnetic units could be built up incorporating the already firmly-established practical units. This is because, using the metre, kilogram and second, the unit of mechanical power becomes 10^7 erg s $^{-1}$, which is the appropriate practical electrical unit, i.e. the watt. The use of the Giorgi system, also known as the mks system, or the Absolute Practical System was approved by an International Electro-technical Commission in 1935. The Absolute Practical System, with the ampere as the electrical base unit was adopted by the CGPM for SI.

RELATIONS BETWEEN THE SYSTEMS OF ELECTRICAL UNITS

Coulomb's law for the force F between charges Q_1 and Q_2 , distance r apart in vacuo, may be expressed in the form

$$F = \frac{Q_1 Q_2}{\epsilon_0 r^2} \quad (1)$$

where ϵ_0 is a constant, called the permittivity of free space. In the cgs electrostatic system, ϵ_0 is chosen to be unity. This choice of the value of ϵ_0 , together with the use of the centimetre, gram and second uniquely determines the system of units.

Ampere's law for the force between two parallel current elements $I_1 ds_1$ and $I_2 ds_2$, distance r apart in vacuo, may be expressed in the form

$$F = \mu_0 \frac{I_1 ds_1 I_2 ds_2 \sin \theta}{r^2} \quad (2)$$

where μ_0 is a constant, called the permeability of free space. In the cgs electromagnetic system μ_0 is chosen to be unity. This choice of the value of μ_0 , together with the use of the centimetre, gram and second, again determines the system of units uniquely.

It may be noted that these two systems of units, defined by $\epsilon_0 = 1$ and $\mu_0 = 1$, cannot be combined directly to form a single consistent system. It can be shown from Maxwell's electromagnetic theory that, in any consistent system of units, $\mu_0 \epsilon_0 = 1/c^2$, where c is the velocity of electromagnetic radiation (e.g. light) in free space, measured in the appropriate units of length and time (e.g. $c \approx 3 \times 10^8$ m s $^{-1}$).

In SI, neither ϵ_0 nor μ_0 is chosen to be unity. The fundamental units chosen are the metre, kilogram, and second and ampere which are sufficient to determine the complete system uniquely. In particular, μ_0 may be shown to have the value 10^{-7} newton ampere $^{-2}$, where the newton is the SI unit of force. This value of μ_0 is readily derived from equation (2). The appropriate value of ϵ_0 is then calculated, knowing the experimentally determined value of the velocity of light.

RATIONALIZATION OF MKS UNITS

It is found that many formulae are simplified if the permeability of free space is re-defined as $\mu_0 = 4\pi\mu_0$. Ampere's law for current elements in free space is then expressed in 'Rationalised mks units' as

$$F = \frac{\mu_0 I_1 ds_1 I_2 ds_2 \sin \theta}{4\pi r^2} \quad (3)$$

where $\mu_0 = 4\pi \times 10^{-7}$ newton ampere $^{-2}$ (or henry metre $^{-1}$).

Similarly, the permittivity of free space is re-defined as $\epsilon_0 = \epsilon_0/4\pi$, and Coulomb's law, for charges in free space, is expressed in rationalised mks units as

$$F = \frac{Q_1 Q_2}{4\pi \epsilon_0 r^2} \quad (4)$$

The value of ϵ_0 , given by $1/c^2 \mu_0$, is approximately 8.85×10^{-12} farad metre $^{-1}$.

For an isotropic, homogeneous medium other than free space, μ_0 in equation (3) is replaced by $\mu = \mu_r \mu_0$, where μ_r is the relative permeability of the medium; and ϵ_0 in equation (4) is replaced by $\epsilon = \epsilon_r \epsilon_0$, where ϵ_r is the relative permittivity (dielectric coefficient) of the medium.

DEFINITIONS OF ELECTRIC AND MAGNETIC QUANTITIES IN SI

The base unit

Current (I): The unit of current is the *ampère* (A), defined as that constant current which, if maintained in each of two infinitely long straight parallel wires of negligible cross-section placed 1 metre apart, in a vacuum, will produce between the wires a force of 2×10^{-7} newtons per metre length.

Derived units

Charge (Q): The unit of charge (quantity) is the *coulomb* (C), defined as the quantity of electricity transported per second by a current of 1 ampere.

Potential Difference (V): The unit of potential difference is the *volt* (V), defined as that difference of electrical potential between two points of a wire carrying a constant current of 1 ampere when the power dissipation between those points is 1 watt.

Resistance (R): The unit of resistance is the *ohm* (Ω), defined as the electrical resistance between two points of a conductor when a constant potential difference of 1 volt applied between these points produces in the conductor a current of 1 ampere.

Conductance (G): The unit of conductance is the *siemens*, (S) defined as the electrical conductance between two points of a conductor when a constant potential difference of 1 volt applied between these points produces in the conductor a current of 1 ampere.

Inductance (L): The unit of inductance is the *henry*, (H) defined as the inductance of a closed circuit in which an electromotive force of 1 volt is produced when the current in the circuit varies uniformly at the rate of 1 ampere per second.

Capacitance (C): The unit of capacitance is the *farad*: (F) defined as the capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by 1 coulomb.

Magnetic Intensity (H): is defined through Ampere's theorem for the intensity due to a current element. In the usual notation $H = \frac{I.d.s.\sin\theta}{4\pi r^2}$. Unit *ampere metre⁻¹*.

Magnetic Flux (Φ) of the induction B : is defined as $\int B.n.dA$ where n is a unit vector perpendicular to an element of area dA . Unit, *weber* (Wb).

Magnetic Flux Density or Induction (B): is defined through the equation for the force on a current element placed in a magnetic field, viz $F = B.I.d.s.\sin\theta$, in the

usual notation. Unit, *Tesla* (T). $B = \mu_r \mu_0 H$ where μ_r is the relative permeability of the medium with respect to free space and μ_0 is the permeability of free space. $\mu_0 = 4\pi \times 10^{-7}$ henry metre⁻¹.

Magnetic Moment (m): is the couple exerted on a magnet placed at right angles to a uniform field with unit flux density. Unit, *ampere metre²*.

Intensity of Magnetisation (M): is the magnetic moment per unit volume of a magnet. Unit, *ampere metre⁻¹*.

Pole Strength (P): On the mks system the hypothetical concept of an isolated magnetic pole is abandoned by many writers on the grounds that all magnetism arises from electrical effects, hence the definitions of H and B (above). Other writers use the idea of a magnetic pole as a simple and convenient concept in magnetometry. In this connection we define a unit magnetic pole as one which when situated 1 metre distant in vacuum from an equal pole experiences a force of $\mu_0/4\pi$ newtons. Alternatively it can be defined as that pole strength which when placed in a unit induction experiences a force of 1 newton. Unit, *ampere-metre*.

Line of Force: A line of force is a curve in a magnetic field, such that the tangent at every point is the direction of the magnetic force at that point.

Magnetomotive Force (F_m): is defined as the line integral $\int H.dl$ evaluated for a closed path. It is equal to the total conduction current linked. Unit, *ampere*.

Coulomb's Magnetic Law: states that the force between two poles P_1 and P_2 situated distance d apart is given by $F = \frac{\mu_r \mu_0 P_1 P_2}{4\pi d^2}$, where μ_r is the permeability of the medium and μ_0 the permeability of the free space = $4\pi \times 10^{-7}$ henry metre⁻¹.

$\mu_r \mu_0$ replaces the permeability μ of the cgs system.

Electrical Intensity (X or E): The electrical intensity at a point in an electric field is the force exerted on unit charge (1 coulomb) placed at that point, assuming that the field is not disturbed by so doing. Unit, *volt metre⁻¹* (which is equivalent to the newton coulomb⁻¹).

Coulomb's Electrostatic Law: appears in the form $F = \frac{Q_1 Q_2}{4\pi \epsilon_0 \epsilon_r d^2}$, where

Q_1 and Q_2 are the two charges situated a distance d apart in a medium whose permittivity relative to that of free space is ϵ_r . The permittivity of free space $\epsilon_0 \approx (1/36\pi) \times 10^{-9}$ farad metre⁻¹. ϵ_r is a pure number. (The product $\epsilon_0 \epsilon_r$ is analogous to the dielectric constant as defined in the cgs system.)

*For these definitions we adopt the Sommerfeld system of units in which the magnetic moment of a current loop is the product of the area of the loop and the current flowing round the edge of the loop: $m = IA$. An alternative system due to Kennelly uses the relation $m = \mu_0 I A$.

DEFINITIONS IN THE CGS ELECTROMAGNETIC SYSTEM OF UNITS

Magnetic Pole (P): When two like magnetic poles are placed 1 cm apart in vacuo, they repel one another with a force of 1 dyne.

Magnetic Field Strength or Intensity (H): is the force experienced by a unit North pole when placed at the given point in a magnetic field, it being assumed that the introduction of the pole does not disturb the field. Unit, *oersted*. The intensity is one oersted when a unit North pole experiences a force of 1 dyne on being placed at the given point in the field. The field strength in vacuum is represented as the number of lines of force passing perpendicularly through 1 cm^2 placed at the point in question. On this convention 4π lines of force leave a unit North pole.

Magnetic Flux (Φ): through any area at right angles to a magnetic field is the product of the area and the field strength. Unit, *maxwell*. One maxwell is the flux through unit area (1 cm^2) placed perpendicularly to a unit uniform field. Hence one line of force is equivalent to one maxwell.

Magnetic Moment (m): of a magnet, is the couple exerted on the magnet when placed at right angles to a unit uniform field. For a bar magnet it is equivalent to the product of the pole strength and the distance between the poles. Unit, *pole cm*.

Magnetic Potential (Ω): is the work done in bringing a unit North pole from infinity or a point of zero potential to the point in question. Unit, *gilbert*. 1 gilbert is that potential which requires the expenditure of 1 erg of work in bringing a unit North pole from infinity to the point.

Intensity of Magnetisation (M): of a sample of material is the magnetic moment per unit volume.

Magnetic Susceptibility (χ): of a material is the ratio of the intensity of magnetisation produced in the sample to the magnetic field which produced the magnetisation. $\chi = \frac{M}{H}$.

N.B.: χ is not a constant but is a function of H .

Magnetic Induction (B): in any material is the number of lines of magnetic force (often called lines of induction) passing perpendicularly through unit area. Unit, *gauss*. One gamma = 10^{-4} gauss.

Magnetic Permeability (μ): of any material is the ratio of the magnetic induction in the sample to the magnetic field producing it, i.e. $\mu = B/H$. Although μ is so defined, B is not proportional to H , for $B = H + 4\pi M$. Also $B/H = 1 + 4\pi M/H$ or $\mu = 1 + 4\pi\chi$. Hence μ is not a constant but a function of H . (see χ above)

Coulomb's Law of Force: states that the force F between two poles of strength P_1 and P_2 is proportional to the product of the pole strengths and inversely proportional to the square of their distance apart (d). Thus $F = \frac{P_1 P_2}{\mu d^2}$ where $1/\mu$ is the constant of proportionality, μ being the permeability of the medium in which the poles are located. In this system, as already stated, the permeability of free space is defined to be unity.

Current (I): The electromagnetic unit (emu) of current is that which when flowing round 1 cm arc of a circle of radius 1 cm, produces a magnetic field of 1 oersted at the centre. Unit, *emu of current*.

Charge (Q): The emu of charge (quantity) is that delivered in 1 second by the passage of unit current. Unit, *biot*.

Potential Difference (P.D.): When unit current flows between two points in a circuit and unit work (1 erg) is done per second, the P.D. between the two points is unity. Unit, *emu of P.D.*

Electromotive Force (emf): When lines of magnetic force cut a conductor an emf is created which is given numerically (in emu) by the number of lines cut per second. $\text{Emf} = dn/dt$.

Resistance (R): A conductor has unit resistance when on applying unit P.D., unit current flows. Unit, *emu of resistance*.

Self Inductance (L): A conductor possesses unit self inductance if unit emf is developed across it when the rate of change of current is unity. Unit, *emu of self inductance*.

Mutual Inductance (M): Two conductors possess unit mutual inductance when unit emf is developed in one by unit rate of change of current in the other. Unit, *emu of mutual inductance*.

DEFINITIONS IN THE CGS ELECTROSTATIC SYSTEM OF UNITS

Electric Charge (Q): When two like unit electrical charges are placed 1 cm apart in vacuum, they repel one another with a force of 1 dyne. Unit, *franklin*.

Electric Field Strength (Intensity) (E): The electric field at a point has unit strength if a unit positive charge experiences a force of 1 dyne when placed at the point, it being assumed that the introduction of the charge does not disturb the field. Unit, *dyne per franklin*.

Electrical Potential (V): is the work done in conveying a unit positive charge from infinity or a point of zero potential to the point in question against the forces of the field. Unit, *erg per franklin*.

Capacitance (*C*): A conductor has unit capacitance when the addition of unit charge raises its potential by unity. Unit, cm.

Dielectric Constant or Specific Inductivity Capacity (ϵ_r): of a material is the ratio of the capacity of a condenser with the material as dielectric to that of the same condenser in vacuum without a material dielectric.

Coulomb's Electrostatic Law of Force: states that the force *F* between two charges Q_1 and Q_2 is proportional to the product of the charges and inversely proportional to the square of their distance apart *d*. Thus $F = \frac{Q_1 Q_2}{\epsilon_r d^2}$, where $1/\epsilon_r$ is the constant of proportionality. ϵ_r is the dielectric constant of the medium in which the charges are located. On the electrostatic system of units, the dielectric constant of free space is unity.

RELATIONS BETWEEN SI, AND CGS ELECTROSTATIC AND ELECTROMAGNETIC UNITS

Quantity and preferred symbol	SI unit and abbreviation	cgs units	
		esu	emu
Mass	<i>m</i>	1 kilogram	kg
Length	<i>l</i>	1 metre	m
Time	<i>t</i>	1 second	s
Current	<i>I</i>	1 ampere	A
Charge	<i>Q</i>	1 coulomb	C
Potential difference	<i>V</i>	1 volt	V
Power	<i>P</i>	1 watt	W
Resistance	<i>R</i>	1 ohm	Ω
Conductance	<i>G</i>	1 siemens	S
Inductance	<i>H</i>	1 henry	H
Capacitance	<i>F</i>	1 farad	F
Magnetic flux	Φ	1 weber	Wb
Magnetic induction	<i>B</i>	1 tesla	T
*Magnetic field strength	<i>H</i>	1 ampere metre $^{-1}$	$A m^{-1}$
*Magnetization	<i>M</i>	1 ampere metre $^{-1}$ Am $^{-1}$	$10^{-1} c$
Electric field strength	<i>E</i>	1 volt metre $^{-1}$	$10^4 c$
Electric displacement	<i>D</i>	1 coulomb metre $^{-2}$	$4\pi \times 10^{-3} c$

NOTE: in the table, *c* represents the speed of light in vacuo. In SI units, $c \approx 3 \times 10^8 \text{ m s}^{-1}$.

*The apparent discrepancy in the conversions of magnetization and magnetic field strength arises from the different definitions of magnetization. Following Sommerfeld, magnetization is now defined by the equation $B = \mu_0(H + M)$. In cgs, it was defined by the equation, $B = H + 4\pi M$. N.B.—For an exhaustive account of systems of electrical units see: L. Young, 'Systems of units in electricity and magnetism'. (Edinburgh, Oliver and Boyd, 1969).

4 Amount of Substance

It is frequently important to express an amount of substance in terms of a fixed number of constituent parts. This has been done by referring to gram-atom or gram-molecule of a substance. In SI, the amount of a substance is expressed relative to a fixed mass of the isotope of carbon containing 6 protons and 6 neutrons in its nucleus, ^{12}C . It is possible to measure the atomic masses of other substances in units of the mass of ^{12}C very accurately.

SI base unit, the Mole (mol)

The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of the carbon isotope ^{12}C . Note: When the mole is used, it is essential to specify the elementary entities under consideration. These may be atoms, molecules, ions, electrons or other particles or groups of particles.

The unified mass unit (u)

As it is possible to measure atomic masses relative to the mass of ^{12}C with extreme accuracy, it is useful to have a mass scale based on the mass of this atom. On the unified mass scale, the mass of the nuclide ^{12}C is set to be exactly 12.0 u.

The chemical and physical mass scales

In past chemical practice, atomic weights were often expressed on the chemical mass scale in which the atomic weight of naturally occurring oxygen was taken to be exactly 16.0. In view of the uncertainty of the isotopic composition of oxygen, another scale, the physical mass scale, came into use. On this scale, the mass of the isotope ^{16}O was set to be exactly 16.0. The IUPAC and the IUCAC jointly agreed in 1959/60 that these scales be discontinued and the unified mass scale used instead.

1 unified mass unit ($^{12}\text{C} = 12$) = $1.000\ 317\ 92$ physical mass unit ($^{16}\text{O} = 16$)

1 unified mass unit = $1.660\ 43 \times 10^{-27}$ kg

1 chemical mass unit = $1.660\ 24 \times 10^{-27}$ kg

The Avogadro constant

Avogadro's law states that under the same conditions of temperature and pressure, equal volumes of all gases contain equal numbers of molecules. Avogadro's number was then defined as the number of entities in a gram-atom or gram-molecule of a substance. Different values of this number were then needed, depending on the mass scale used. In SI, the Avogadro constant is defined as the number of atoms in 0.012 kg of the isotope, ^{12}C , and is thus the number of entities in a mole of substance.

5 Heat Units and Definitions

Temperature (*t*, θ or *T*): In SI, temperatures are measured on the thermodynamic scale with the Absolute Zero as zero and the triple point of water (i.e. the temperature at which ice, water and water vapour are in equilibrium) as the upper fixed point. The thermodynamic scale is that given by a theoretical Carnot heat engine and is equal to the perfect gas scale.

SI base unit, the Kelvin (K). The kelvin (K) unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

The Degree Celsius (°C). The centigrade scale of temperature used the ice point as zero and the boiling point of water at 1 standard atmosphere as the upper fixed point set to be 100°C. The Celsius scale of temperature is defined to be the same as the thermodynamic scale with the zero shifted to the ice point, which is 273.15 K, and thus:

$$\theta/^\circ\text{C} = T/\text{K} - 273.15$$

The International Practical Scale of Temperature (IPST). In view of the difficulty of measuring on the thermodynamic scale, a scale of temperature based on fixed points was suggested by the 7th CCPM in 1927. The scale has been revised since so as to make temperatures on this scale agree as nearly as possible with the thermodynamic Celsius scale. A list of the fixed points and other important temperatures will be found on p. 70.

The Degree Fahrenheit (°F). On the Fahrenheit scale, the ice point is 32°F and the steam point, 212°F. Thus $t/^\circ\text{F} = 32 + 1.8(\theta/^\circ\text{C})$.

The Degree Reaumur (°R). On the Reaumur scale, the ice point is 0°R and the steam point, 80°R. Thus $t/^\circ\text{R} = 0.8(\theta/^\circ\text{C})$.

Quantity of Heat (Q). Quantities of heat are measured in joules (J) in SI. Other units have been used, notably the *calorie*. The calorie is the amount of heat required to raise the temperature of 1 gram of water by 1°C. This definition is not very precise however as the specific heat capacity of water varies with temperature. The 15° *calorie* was defined as the heat required to raise the temperature of 1 g of water from 14.5 °C to 15.5°C. The *mean calorie* was defined as one hundredth of the heat required to raise the temperature of 1 g of water from 0°C to 100°C. The *kilocalorie* (1 000 calories) has also been used and written Calorie. Where quantities of heat are expressed in calories, it is recommended that the conversion factor to convert to joules be stated.

In the fps system, the *British thermal unit* (Btu) is used. This is the quantity of heat required to raise the temperature of 1 lb of water through 1°F. The therm is 10^3 Btu.

Specific Heat Capacity (c_p, c_v). This is the amount of heat required to raise the temperature of 1 kg of a substance 1 K. Units, $\text{J kg}^{-1} \text{K}^{-1}$.

Molar Heat Capacity (C_m). This is the amount of heat required to raise the temperature of 1 mol of substance through 1 K. Units, $\text{J mol}^{-1} \text{K}^{-1}$.

Heat Capacity (C). The amount of heat required to raise the temperature of a body through 1 K. Units, J K^{-1} .

Water Equivalent. The mass of water having the same total heat capacity as the given body.

Thermal Conductivity (λ). The rate of flow of heat (dQ/dt) through a surface of area, A , in a medium is given by:

$$\frac{dQ}{dt} = -\lambda A \frac{dT}{dx}$$

where (dT/dx) is the temperature gradient, measured in the direction normal to the surface. The quantity λ , is the thermal conductivity of the medium. Units, $\text{J m}^{-1} \text{s}^{-1} \text{K}^{-1}$, or $\text{W m}^{-1} \text{K}^{-1}$.

Specific Latent Heat (l). The specific latent heat of fusion (specific enthalpy change on fusion) of a body is the heat required to convert 1 kg of the solid at its melting point into liquid at the same temperature. Unit, J kg^{-1} .

The specific latent heat of vaporization (enthalpy change on vaporization) of a liquid is the heat required to convert 1 kg of the liquid at its boiling point into vapour at the same temperature. Unit, J kg^{-1} .

Linear Expansivity (α). The increase in length per unit length per unit rise in temperature. Unit, K^{-1} .

Cubic Expansivity (γ). The increase in volume per unit volume per unit rise in temperature. Unit, K^{-1} .

Critical Temperature (T_c). of a gas or vapour is that temperature above which it is not possible to liquefy the gas by the application of pressure alone. To liquefy a gas it must be cooled below its critical temperature before being compressed.

Critical Pressure (p_c): That pressure which just liquefies a gas at its critical temperature.

Critical Volume (V_c): The volume of unit mass of gas at its critical temperature and pressure, i.e. it is the reciprocal of the critical density. It is often taken as the volume of one mole of a gas at its critical temperature and pressure.

Radiation. Stefan-Boltzmann Law: The total energy, E , of all wavelengths radiated per second per square metre by a full radiator at temperature T to surroundings at T_0 is given by $E = \sigma(T^4 - T_0^4)$, where σ is Stefan's constant. $\sigma = 5.669 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$.

Planck's Radiation Law: The energy density of radiation in an enclosure at temperature T having wavelengths in the range λ to $\lambda + d\lambda$ is $u_\lambda d\lambda$, where

$$u_\lambda d\lambda = 8\pi ch\lambda^{-5}(\exp hc/kT - 1)^{-1} d\lambda = c_1 \lambda^{-5}(\exp c_2/\lambda T - 1)^{-1} d\lambda$$

$$c_1 = 4.992 \times 10^{-24} \text{ J m} \quad c_2 = 1.438 \times 10^{-2} \text{ m K}$$

The corresponding relation for radiation of frequency, v , is

$$u_v dv = (8\pi h/c^3)(\exp hv/kT - 1)^{-1} v^2 dv$$

h = Planck's constant; c = speed of light; k = Boltzmann's constant; T = temperature of the enclosure.

Wien's Displacement Law: The wavelength of the most strongly emitted radiation in the continuous spectrum from a full radiator is inversely proportional to the absolute temperature of that body, i.e. $\lambda T = b$, where b is Wien's constant = $2.898 \times 10^{-3} \text{ m K}$.

The Energy (E) of a quantum of radiation of frequency v is $E = hv$ where h is Planck's constant.

Luminous Intensity. In SI, the unit of luminous intensity is the candela. This unit replaces the International candle which was defined in terms of the light emitted per second in all directions by a specified electric lamp.

SI base unit, the candela (cd). The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 square metre of a full radiator at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre.

$$1 \text{ candela} = 0.982 \text{ international candles.}$$

Luminous flux: The unit of luminous flux, the lumen (lm) is defined as the light energy emitted per second within unit solid angle by a uniform point source of unit luminous intensity. Thus $1 \text{ cd} = 1 \text{ lm sr}^{-1}$.

Illuminance of a surface is defined as the luminous flux reaching it perpendicularly per unit area. The British unit is the lumen ft^{-2} , formerly called the foot candle (f.c.). The metric unit is the lumen m^{-2} or lux (lx).

Lambert's Cosine law: For a surface receiving light obliquely, the illumination is proportional to the cosine of the angle which the light makes with the normal to the surface.

Brightness of a surface is that property by which the surface appears to emit more or less light in the direction of view. This is a subjective quantity. The corresponding physical measurement of the light actually emitted is called the luminance.

Luminance of a surface is the measure of the light actually emitted (*i.e.* the luminous intensity) per unit projected area of surface, the plane of projection being perpendicular to the direction of view. Unit, cd ft^{-2} or cd m^{-2} . In engineering, the luminance of an ideally diffusing surface emitting or reflecting one lumen ft^{-2} is called one foot-lambert (ft-L).

The Refractive index of a material (n) is the ratio of the velocity of light in free space to that in the material.

Snell's law: For light incident on a boundary between two media, the ratio of the sine of the angle of incidence (the angle between the light ray in the first medium and the normal to the boundary surface) to the sine of the angle of refraction (the angle between the refracted ray in the second medium and the normal) is a constant, being equal to the inverse ratio of the refractive indices of the two media.

Dioptric is the unit of measure of the power of a lens and is given numerically by the reciprocal of the focal length expressed in metres.

7 Acoustical Units and Definitions

Pressure: The unit of sound pressure is the pascal usually quoted as the root mean square (r.m.s.) pressure for a pure sinusoidal wave.

Frequency: The unit of frequency is the cycle per second, now designated the hertz (Hz).

Threshold of Hearing is, for a normal (average) observer, the sound level or intensity which is just audible. For a pure sinusoidal note of frequency 1000 Hz it is close to a root mean square pressure of 2×10^{-5} Pa.

Power Ratio: The unit of acoustical (or electrical) power measurement with respect to a standard level, is one bel. The interval between two powers W_1 and W_0 in bels is $\log_{10} (W_1/W_0)$. In practical work the decibel (dB) is used. The interval between two powers W_1 and W_0 is $10 \log_{10} (W_1/W_0)$ dB. In some instances it is more convenient to employ natural logarithms. The power ratio so obtained is called the neper and is defined as follows. The power interval between W_1 and W_0 is $\frac{1}{2} \log_e (W_1/W_0)$ nepers. Hence $1 \text{ neper} = 8.686 \text{ dB}$.

Intensity (I) of a sound wave in a given direction is the sound energy transmitted per second in this direction through unit area placed perpendicularly to the specified direction. Unit, W m^{-2} . For a sinusoidal plane or spherical wave, the intensity is proportional to the mean square pressure exerted on an area at right angles to the given direction. Hence the interval between two intensities is given by $10 \log_{10} (I_1/I_0)$ dB or $20 \log_{10} (p_1/p_0)$ dB where p_1 and p_0 are the r.m.s. pressures corresponding to the intensities I_1 and I_0 .

Loudness is the physiological counterpart of acoustical intensity. It is a function of the intensity but also varies with frequency and composition of the note being heard. The *Weber-Fechner Law* states that the sensation (loudness) is proportional to the logarithm of the stimulus (intensity).

Loudness level of a sound is judged by comparison in free air with a standard sinusoidal note whose frequency is 1000 Hz. The unit is the *phon*. If an average observer decides that a sound is equally loud as the standard 1000 Hz note of intensity n dB above the standard reference level corresponding to a r.m.s. pressure of 2×10^{-5} Pa (*i.e.* the threshold of hearing), then the sound is said to have an 'equivalent loudness' of n British Standard phons.

Reverberation in an enclosure is the persistence of sound due to multiple reflections from the walls, etc. of the enclosure.

Reverberation time is the time required, from the moment of cessation of a sound for the intensity to drop by 60 dB, *i.e.* to one millionth of its original value. Unit, *second*.

Absorption Coefficient of a surface is the ratio of the sound energy absorbed to the total sound energy incident on the surface. The ideal absorber is one from which no sound is reflected or scattered. For unit area of various substances, the coefficient is expressed in terms of equivalent area of open window (diffraction effects excluded). Unit, *ft² of open window* or *Sabine*. The coefficient varies with frequency.

Sabine's Relation: For an auditorium whose walls, etc. consist of areas $S_1 S_2 \dots$ etc. of absorption coefficient $\alpha_1 \alpha_2 \dots$ etc., the reverberation time t (in seconds) is given by $t = 0.05V$ (unit of length, ft) or $t = 0.16V$ (unit of length, metre)

$$\frac{\Sigma \alpha S}{\Sigma S}$$

where V is the volume of the auditorium and $\Sigma S = \alpha_1 S_1 + \alpha_2 S_2 + \dots$ etc.

88 The Periodic Table—giving atomic number and chemical symbol for each element

The Advancement of Science in Africa

The table below gives the numbers of electrons in the various shells of the atoms. It refers to neutral atoms in their lowest energy states. The usual notation is used for the shells. The number refers to the principal quantum number and the letter to the angular quantum number. The letters a, b, c, d, e, f, g denote shells outside the innermost shell.

10 Properties of the Elements

The following table lists the elements with atomic number up to 92 alphabetically by name. Columns 1-4 and 13-16 are self-explanatory. Column 5 gives the crystal structures of the elements in their solid state. Where a change in structure occurs, the transition temperature is indicated (in K) under the crystal structures. The following abbreviations are used:

bcc = body-centred cubic
 cubic (diam) = diamond structure
 fcc = face-centred cubic
 hcp = hexagonal close-packed

hex = hexagonal

mon = monoclinic

ortho = orthorhombic

tetra = tetragonal

Column 6 lists the atomic radii of the elements in pm (10^{-12} m). These radii are calculated on half the distance of closest approach of atomic centres in the crystalline state. Column 7 gives the principal oxidation numbers and column 8, the corresponding ionic radii. Columns 9 and 10 give the energies (eV) required to remove the first and second electrons from the atoms—multiplied by 96.49 to convert to kJ mol⁻¹. Column 11 gives the energy required to remove an electron from the negative ion formed by the atom with an extra electron. These 'electron affinities' are difficult to measure and there are few reliable results. Column 12 gives the electronegativities assigned to the elements by Pauling. These are numbers between 0 and 4 which may be used in determining the contribution of the ionic and covalent components of the bonds between different atoms.

Symbol	Name	Atomic Number	Atomic Weight	Atomic Weight/M g mol ⁻¹	Crystal Structure	Atomic radius/ pm	Principle Oxidation Numbers	Lattice Radius/ pm	Lattice Parameters/ pm	Ionization Energies/EV	Electron Affinities/eV	Electronegativities	Density/ kg m^{-3}	Melting Point/ $^{\circ}\text{K}$	Boiling Point/ $^{\circ}\text{K}$	Symbol	
Ac	Actinium	89	227	26.98	fcc	188	3+	118	6.9	12.1	—	1.1	10.100	1.320	3.470	Ac	
Al	Aluminium	13	26.98	121.75	fcc/rhombo	142	3+	51	5.986	18.828	0.5	1.3	2.700	9.33-2	2.740	Al	
Sb	Antimony	51	121.75	—	—	145	3+	51	8.641	16.53	>2.0	1.9	6.700	9.03-7	1.650	Sb	
Ar	Argon	18	39.95	39.92	fcc	174	0(1+)	134	15.759	27.629	-1.0	—	1.66	8.37	8.74	Ar	
As	Arsenic	33	74.92	74.92	fcc/rhombo	125	3+	54	9.81	18.633	—	2.0	5.730	1.090	8.86	As	
At	Astatine	85	210	137.34	bcc	—	7+	62	9.5	—	—	2.2	5.520	(29 atm)	623	At	
Be	Beryllium	4	9.01	12.04	hcp/cubic	1327	112	35	5.112	10.004	—	0.9	3.600	1.000	1.910	Be	
Bi	Bismuth	83	208.98	208.98	rhombo	155	3+	96	7.289	16.69	>0.7	1.9	1.800	1.550	3.243	Bi	
B	Boron	5	10.81	10.81	ortho (7)	88	3+	23	8.298	25.154	0.33	2.0	2.500	2.600	2.820	B	
Br	Bromine	35	79.90	79.90	ortho	114	1-	196	11.814	21.8	3.363	2.8	3.100	(298 K)	265.9	331.9	Br
Cd	Cadmium	48	112.40	112.40	hcp	148	2+	97	8.993	16.908	>0.19	1.7	8.650	5.94-2	1.038	Cd	
Ca	Calcium	20	40.08	40.08	fcc/bcc 73%	196	2+	167	3.894	25.1	—	0.7	1.870	3.01-6	9.60	Cs	
Ca	Calcium	20	40.08	40.08	hex/cubic	71/77	4+	92	6.113	11.671	—	1.0	1.540	1.120	1.760	Ca	
C	Carbon	6	12.01	12.01	graph/diam	Ed	4-	16	11.260	24.383	1.25	2.5	2.300	>3.800	5.100	C	

Co	Cerium	58	140-12	fcc/hex/fcc/bcc	183	3+	103	5-47	10-85	—	1.1	6.800	1.070	3.740	Co	
Cl	Chlorine	17	35.45	95	263.998	91	1-	181	12.967	23.81	3-615	3-0	3.21	172.1	238.5	Cl
Cr	Chromium	24	52.00	bcc	125	5+	34	6.766	16.50	0.98	1-6	7.200	2.160	2.755	Cr	
Co	Cobalt	27	58.93	hcp/fcc	125	3+	63	52	7.86	17.06	0.9	1-8	8.900	1.765	3.170	Co
Cu	Copper	29	63.55	fcc	128	1+	96	7.726	20.292	1.8	1-9	8.930	1.356	2.868	Cu	
Dy	Dysprosium	66	162.50	hcp	175	3+	91	5.93	11.67	—	1.2	8.500	1.680	2.900	Dy	
Er	Erbium	68	167.26	hcp	173	3+	88	6.10	11.93	—	1.2	9.000	1.700	3.200	Er	
Eu	Europium	63	151.96	bcc	198	3+	95	5.67	11.25	—	1.1	5.200	1.100	1.712	Eu	
F	Fluorine	9	19.00	—	60	1-	133	17.422	34.97	3.448	4-0	1.7	53.5	85.0	F	
Fr	Francium	87	223	hcp/bcc 1337	178	7+	8	187	4.0	—	0.7	(273 K)	305	920	Fr	
Gd	Gadolinium	64	157.25	hcp/bcc 1337	121	1+	94	6.14	12.1	—	1.2	7.900	1.585	3.060	Gd	
Ga	Gallium	31	69.72	fcc or ortho	144	3+	81	9.225	20.5	2-1	2-4	19.300	1.336-1	3.239	Ga	
Ge	Germanium	32	72.59	cubic (diam)	122	4+	53	7.899	15.934	—	1.8	5.400	1.210-5	3.100	Ge	
Ag	Gold	79	196.97	fcc	144	1+	137	9.225	20.5	—	1.6	5.950	3.029	2.676	Ag	
Hf	Hafnium	72	178.49	hcp/bcc 2550	158	4+	78	7.0	14.9	—	1.3	13.360	2.423	5.700	Hf	
He	Helium	2	4.003	hcp/cubic	176	0	—	24.587	54.416	0-53	—	0-166	(26 atm)	0-95	4.21	He
Ho	Holmium	67	164.93	hcp	176	3+	89	6.02	11.80	—	1-2	8.800	1.734	2.900	Ho	
H	Hydrogen	1	1.00797	hcp/cubic	46	1+	154	13.598	—	0-76	2-1	(273 K)	14-01	20-4	H	
In	Indium	49	114.82	bc tetra	162	3+	61	5.795	18.069	—	1-7	7.310	429.8	3.300	In	
I	Iodine	53	116.90	ortho	135	4+	68	9.4	16.451	19.131	3-070	2-2	22.420	4.940	457.4	I
Fr	Krypton	77	182.2	fcc/bcc/bcc	123	2+	74	7.87	16.16	0-6	1-8	7.870	1.808	4.000	Fr	
Fe	Iron	26	55.05	1180.1670	201	0	—	13.999	24.359	—	1-1	6.150	1190	3.742	Fe	
Kr	Krypton	36	83.90	fcc/bcc/bcc	187	1+	139	5.577	11.06	—	—	3-49	116.5	120.8	Kr	
Ca	Lanthanum	97	139.91	fcc	533	1.37	102	120	7.416	15.032	—	1-8	11.340	600-4	2.017	La
Pb	Lanthanum	92	207.99	fcc	174	2+	84	84	3.392	75.638	0-82	1-0	534	452	1.390	Pb
Tl	Thallium	3	6.96	hcp/bcc	152	1+	68	—	—	—	—	—	—	—	—	Tl
Li	Uranium	74	140	—	—	—	—	—	—	—	—	—	—	—	—	Li

	Ra	Radium	226	143	5-279	10-147	—	1-410	Ra
	Rn	Radon	222	0	10-748	—	—	211-3	Rn
Re	Rhenium	186-2	hep	137	72	7-88	16-6	0-9	5-000
Rh	Rhodium	102-91	fec	134	4+	7-46	18-08	0-15	(27.3 K)
Rb	Rubidium	85-47	bcc	246	3+	4-77	27-28	0-4	2-2
Ru	Ruthenium	113	hep	133	4+	7-374	16-76	—	12-440
Sm	Samarium	150-35	Rhomb/bcc	179	3+	5-63	11-07	—	2-2
Sc	Scandium	44-96	hep/fcc 1223	160	3+	6-54	12-80	—	2-2
Se	Selenium	78-96	hep	116	2-	191	9-752	21-19	2-2
Si	Silicon	28-09	cubic	118	{ 4+	81-51	16-345	3-7	3-000
Ag	Silver	107-87	fcc/hcp 5	144	{ 4-	38	1-5	1-8	Sc
Na	Sodium	22-99	bcc	185	1+	126	5-139	21-49	4-800
Sr	Strontium	87-62	fec/hep/bcc	215	2+	1+ 97	47-286	2-5	5-900
S	Sulphur	506	81-3	506	fe ortho.	112	5-695	11-030	6-000
Ta	Tantalum	32-06	fe	106	{ 2-	184	10-360	23-33	7-070
Tc	Technetium	180-95	bcc	143	{ 4+	37	7-89	16-2	2-070
Tc	Tellurium	98-91	hep	135	5+	68	7-28	15-26	3-076
Tb	Terbium	127-60	hep	143	7+	98	9-099	18-6	3-076
Tl	Thallium	158-92	hep/rhom	177	2-	211	11-52	3-6	3-076
Tl	Thallium	1590	hep	171	1+	147	6-108	20-428	3-076
Th	Thorium	212-04	hep/bcc 1673	180	4+	102	6-95	11-5	1-8
Tm	Thulium	168-93	hep/bcc 1158	174	3+	87	6-18	12-05	1-8
Tin	Tin	118-69	cub(diam)/bcc	140	{ 2-+	93	7-344	16-632	1-8
Ti	Titanium	47-90	hep/bcc 1158	146	{ 4-+	71	6-82	13-58	0-39
W	Tungsten	183-85	bcc	137	6-+	62	7-98	17-7	0-5
U	Uranium	238-03	rhom/bcc/tear 94%	138	{ 4-+	97	6-08	—	0-96
V	Vanadium	50-94	bcc	131	{ 6-+	80	74	6-74	14-65
Yc	Yttria	131-30	fec	221	{ 5-+	59	5-59	12-130	21-21
Yb	Ytterbium	173-04	fec/bcc 1071	193	0	—	86	6-254	1-2
Yt	Yttrium	88-91	hep/bcc 1763	181	3+	89	6-38	12-24	1-2
Zn	Zinc	65-37	hep	133	3-+	74	9-394	17-964	1-6
Zn	Zinc	91-37	hep	133	2+	74	6-94	17-964	1-6

11 Properties of Metallic Solids (at 293 K)

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Values quoted for Tensile Strength and Yield Stress are in units of 10^6 N m^{-2} (= MPa). Values of Young's Modulus are in units of 10^9 N m^{-2} (= GPa). These values are typical observations and are approximate only. The elastic properties vary somewhat between specimens depending on the manufacturing process and the previous history of the sample. The Shear Modulus (G) and Bulk Modulus (K) can be calculated from the relations: $G = \frac{E}{2(1 + \nu)}$ and $K = \frac{E}{3(1 - 2\nu)}$, where E is Young's Modulus and ν is Poisson's Ratio.

Name	Density $\rho/\text{kg m}^{-3}$	Melting Point T_m/K	Specific Latent Heat of Fusion $l/\text{J kg}^{-1}$	Specific Heat Capacity $c_p/J \text{ kg}^{-1} \text{ K}^{-1}$	Linear Expansivity $\alpha \times 10^{-6} \text{ /K}$	Thermal Conductivity $\lambda/\text{W m}^{-1} \text{ K}^{-1}$	Electrical Resistivity $\rho/\Omega \text{ m}$	Temperature Coefficient of Resistance $(1/\rho_0) (\Delta\rho/\Delta T) \text{ K}^{-1}$	Tensile Strength σ_t/MPa	Yield Strength σ_y/MPa	Elongation: $\epsilon/\%$	Young's Modulus E/GPa	Poison's Ratio ν	
1 Aluminium	2 710	932	38	913	23	201	2.65	40	80	50	43	71	0.34	1
2 Aluminium, strong alloy	2 800	800	39	880	23	180	5	16	600	550	10			2
3 Antimony	6 680	904	16	205	10	18	40	~ 50				78		3
4 Bismuth	9 800	544	5	126	13	8	115	~ 45				32	0.33	4
5 Brass (70Cu/ 30Zn)	8 500	1300		370	18	110	~ 8	~ 15	550	450	8	100	0.35	5
6 Bronze (90Cu/ 10Sn)	8 800	1300		360	17	180	30		260	140	10			6
7 Cobalt	8 900	1765	25	420	12	69	6	66	~ 500					7
8 Constantan	8 880	1360		420	17	23	47	± 0.4				170	0.33	8
9 Copper	8 930	1356	21	385	17	385	1.7	39	150	75	45	117	0.35	9
10 German silver (60Cu/25Zn/ 15Ni)	8 700	1300		400	18	29	33	4	450			130	0.33	10
11 Gold	19 300	1340	7	132	14	296	2.4	34	120		40	71	0.44	11
12 Invar (64Fe/36Ni)	8 000	1800		503	0.9	16	81	20	480	280	40	145	0.26	12
13 Iron, pure	7 870	1810	27	106	12	80	10	65	300	165	45	206	0.29	13
14 Iron, cast grey	7 150	1500	10	500	11	75	10		100			110	0.27	14
15 .. " white	7 700	1420	14		11	75	10		230					15
16 .. " wrought	7 850	1810	14	480	12	60	14	60	~ 370	150	45	197	0.28	16
17 Lead	11 340	600	2.6	126	29	35	21	43	15	12	50	18	0.44	17
18 Magnesium	1 740	924	38	246	25	150	4	43	190	95	5	44	0.29	18
19 Manganin	8 500	41	400		18	22	45	± 0.1				120	0.33	19
20 Monel (70Ni/ 30Cu)	8 800	1600	-		14	210	42	20	520	240	40			20
21 Nickel	8 900	1726	31	460	13	59	59	60	300	60	30	207	0.36	21
22 Nickel, strong alloy	8 500	1320		380					1300	1200	10	110	0.38	22
23 Phosphor bronze					17		7	60	560	420		120	0.38	23
24 Platinum	21 450	2042	11	136	9	69	11	38	350	-		150	0.38	24
25 Silver	10 500	1230	10	235	19	419	1.6	40	150	180	45	70	0.37	25
26 Sodium	970	371	12	1240	71	134	4.5	44						26
27 Solder, soft (50Pb/50Sn)	9 000	490	190	176					45		50			27
28 Stainless Steel! (18Cr/8Ni)	7 930	1800		510	16	150	96	6	600	230	60			28
29 Steel, mild	7 860	1700		420	15	63	15	50	460	300	35	210	0.29	29
30 Steel, piano wire	7 800	1700				50			3000			210	0.29	30
31 Tin	7 300	505	6.0	226	23	65	11	50	30			40	0.36	31
32 Titanium	4 540	1950		523	9	23	53	38	620	480	20		0.36	32
33 Zinc	7 140	693	10	385	31	111	5.9	40	150		50	110	0.25	33

12 Properties of Non-Metallic Solids (at 293 K)

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The following table lists materials which do not readily conduct electricity. In many cases the physical constants cannot be specified accurately as the values observed depend so much on the manufacture and life history of the specimen. The values given are to be taken as representative only.

13 Properties of Liquids (at 293 K)

Name	Density $\rho/\text{kg m}^{-3}$	Melting Point T_m/K	Boling Point T_b/K	Specific Latent Heat of Vaporization $U/\text{J kg}^{-1}$	Specific Heat $C_p/\text{J kg}^{-1}\text{K}^{-1}$	Cubric Expansion α/K^{-1}	Thermal Conductivity $\lambda/\text{W m}^{-1}\text{K}^{-1}$	Surface Tension $\sigma/\text{N m}^{-1}$	Viscosity $\eta/\text{Ns m}^{-2}$	Reflective Index n	Bulk Modulus of Rigidity K/GPa
1 Acetic acid ($\text{C}_2\text{H}_4\text{O}_2$)	1049	290	391	330	178	$\times 10^4$	1960	10.7	0.180	27.6	2.49
2 Acetone ($\text{C}_3\text{H}_6\text{O}$)	780	279	353	40	1700	$\times 10^4$	14.3	0.161	23.7	0.324	1.3620
3 Benzene (C_6H_6)	879	266	332	18.3	460	$\times 10^4$	11.3	0.140	28.9	0.647	1.5011
4 Bromine (Br_2)	1300	162	319	36	1000	$\times 10^4$	11.9	0.144	41.5	0.993	1.66
5 Carbon disulphide (CS_2)	1293	250	350	19	840	$\times 10^4$	12.2	0.103	32.3	0.375	1.6276
6 Carbon tetrachloride (CCl_4)	1632	250	350	19	2000	$\times 10^4$	12.2	0.103	26.8	0.972	1.4607
7 Chloroform (CHCl_3)	1490	210	334	25	960	$\times 10^4$	12.7	0.121	27.1	0.569	1.4467
8 Ether, diethyl ($\text{C}_4\text{H}_{10}\text{O}$)	714	157	308	35	2300	$\times 10^4$	16.3	0.127	17	0.242	1.3538
9 Ethyl alcohol ($\text{C}_2\text{H}_5\text{OH}$)	789	156	352	85	2500	$\times 10^4$	10.8	0.177	22.3	1.197	1.3610
10 Glycerol ($\text{C}_3\text{H}_8\text{O}_3$)	1262	293	563	83	2400	$\times 10^4$	4.7	0.270	63	1.495	1.4730
11 Mercury (Hg)	13546	234	630	29	140	$\times 10^4$	1.82	0.201	472	1.552	1.73
12 Methyl alcohol (CH_3O)	791	179	337	112	2500	$\times 10^4$	11.9	0.160	22.6	0.594	1.3276
13 Nitrobenzene ($\text{C}_6\text{H}_5\text{NO}_2$)	1175	279	484	33	1400	$\times 10^4$	8.6	0.160	43.9	2.03	1.5530
14 Olive oil	920	570	570	2130	900	$\times 10^4$	7.0	0.170	32	84	1.48
15 Paraffin oil	800	1073	314	455	53	$\times 10^4$	0.150	0.150	40.9	~ 1000	1.43
16 Phenol ($\text{C}_6\text{H}_5\text{O}$)	998	870	263	429	29	$\times 10^4$	1670	10.7	0.134	12.74	1.5425
17 Toluene (C_7H_8)	867	178	384	35	1760	$\times 10^4$	9.7	0.136	27	1.49	(213 K)
18 Turpentine (C_7H_8)	870	273	373	226	4190	$\times 10^4$	0.591	0.591	72.7	1.000	1.4969
19 Water (H_2O)	1025	264	~ 377	~ 377	3900	$\times 10^4$	~ 1000	~ 1000	~ 1000	1.09	1.09
20 Water, sea										1.343	1.343

14 Properties of Gases at S.T.P.

Substance	Density $\rho/\text{kg m}^{-3}$	Boling Point T_b/K	Specifc Latent Heat of Vaporization $U/\text{J kg}^{-1}$	Specifc Heat $C_p/\text{J kg}^{-1}\text{K}^{-1}$	Ratio of Specific Heats $\gamma = (C_p/C_v)$	Thermal Conductivity $\lambda/\text{W m}^{-1}\text{K}^{-1}$	Viscosity $\eta/\text{Ns m}^{-2}$	Refraactivity $(n-1)/\lambda$	Critical Pressure P/MPa	Critical Volume $V/\text{m}^3 \text{mol}^{-1}$	$\times 10^{-6}$
1 Acetylene (C_2H_2)	1.173	189	$\times 10^4$	1590	1.26	$\times 10^4$	184	9.35	606	309	6.14
2 Air	1.293	83	21.4	993	1.402	241	18.325 (300 K)	9.18	292	132	3.77
3 Ammonia (NH_3)	0.771	240	137.1	2190	1.310	218	9.18	376	405	1.3	72.5
4 Argon (Ar)	1.784	87	15.8	524	1.667	162	21	151	486	7.38	4.4
5 Carbon dioxide (CO_2)	1.977	195	36.4	834	1.304	145	14	451	304	94.0	5.6
6 Carbon monoxide (CO)	1.230	.81	21.1	1050	1.404	232	16.6	338	134	3.50	93.1
7 Chlorine (Cl_2)	2.324	238	28.1	478	1.36	72	12.9	773	417	7.71	124
8 Cyanogen (C_2N_2)	2.327	252	43.2	1720	1.26	164	9.7	835	283	5.12	127.4
9 Ethylene (C_2H_4)	1.630	170	48.4	1500	1.26	145	18.6	36	5.3	0.23	58
10 Helium (He)	0.179	4.25	2.5	5240	1.66	141	1.41	1334	132	33.3	12.94
11 Hydrogen (H_2)	0.090	20.35	45.3	14300	1.41	1534	8.35	447	447	325	65.5
12 Hydrogen chloride (HCl)	1.640	189	41.4	796	1.40	1.40	13.6	1.40	60	8.26	87
13 Hydrogen sulphide (H_2S)	1.338	211	15.3	1020	1.32	120	11.7	634	374	9.01	97.9
14 Methane (CH_4)	0.717	105	51.1	2200	1.313	302	10.3	444	191	4.62	98.7
15 Nitric oxide (NO)	1.340	121	46.2	972	1.394	238	17.8	297	179	6.5	15
16 Nitrogen (N_2)	1.250	77	20.9	1640	1.404	243	16.7	297	126	3.39	50.1
17 Nitrous oxide (N_2O)	1.978	183	37.6	892	1.303	151	13.5	316	310	7.24	36.7
18 Oxygen (O_2)	1.429	90	26.3	913	1.40	244	19.2	272	154	5.08	78
19 Sulphur dioxide (SO_2)	2.927	263	49.3	645	1.26	77	11.7	636	430	7.88	122
20 Water vapour (273 K) (H_2O)	0.890		225.1	2020	1.373 (273 K)	158	8.7	647	254	22.12	36.6

*The critical volume is also called as the size of the molecule at its critical temperature and pressure.

15 Mechanical Data

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THE MOHS SCALE OF HARDNESS

Substance	Hardness	Substance	Hardness	Substance	Hardness
Talc	1	Felspar	6	Fused zirconia	11
Gypsum	2	Vitreous silica	7	Fused alumina	12
Calcite	3	Quartz	8	Silicon carbide	13
Fluorite	4	Topaz	9	Boron carbide	14
Apatite	5	Garnet	10	Diamond	15

APPROXIMATE HARDNESS OF SOME COMMON MATERIALS

Substance	Hardness	Substance	Hardness	Substance	Hardness
Agate	6-7	Calcium	1.5	Glass	4.5-6.5
Aluminium	2-3	Carborundum	9-10	Marble	3-4
Amber	2-2.5	Chromium	9	Penknife blade	6.5
Asbestos	5	Copper	2.5-3	Silver	2.5-2.7
Brass	3-4	Finger nail	2.5	Steel (mild)	4-5

VISCOSITIES OF LIQUIDS AND THEIR TEMPERATURE DEPENDENCE,

$\eta/N \text{ s m}^{-2}$

Substance	0°C	10°C	20°C	30°C	40°C	50°C
Water	0.001787	0.001304	0.001002	0.00080	0.000653	0.000547
Aniline	0.0102	0.0065	0.0044	0.00316	0.00237	0.00185
Benzene	0.000912	0.000758	0.000652	0.000564	0.000503	0.000442
Ethanol	0.00177	0.00147	0.0012	0.00100	0.000834	0.00070
Glycerol (propane-1,2,3-triol)	10.59	3.44	1.34	0.629	0.289	0.141
Rape oil	2.53	0.385	0.163	0.096	—	—

16 Electrical and Magnetic Data

IMPERIAL STANDARD WIRE GAUGE (SWG) AND WIRE RESISTANCES

Gauge Number	Diameter mm	Sectional Area mm ²	Copper Ohm per metre	Eureka Ohm per metre	German Silver Ohm per metre	Manganin Ohm per metre	Nichrome Ohm per metre	Gauge Number
10	3.251	8.3019	0.00208	0.0590	0.0273	0.0500	0.130	10
12	2.642	5.4805	0.00315	0.0894	0.0413	0.0757	0.197	12
14	2.032	3.2429	0.00532	0.151	0.0698	0.128	0.333	14
16	1.626	2.0755	0.00831	0.236	0.109	0.200	0.520	16
18	1.219	1.1675	0.0148	0.420	0.194	0.355	0.925	18
20	0.9144	0.6567	0.0263	0.746	0.345	0.632	1.64	20
22	0.7112	0.3973	0.0434	1.23	0.570	1.04	2.72	22
24	0.5588	0.2453	0.0703	2.00	0.923	1.69	4.40	24
26	0.4572	0.16417	0.105	2.98	1.38	2.53	6.58	26
28	0.3759	0.11099	0.135	4.41	2.04	3.74	9.73	28
30	0.3150	0.07791	0.221	6.29	2.91	5.33	13.9	30
32	0.2743	0.05910	0.292	8.29	3.83	7.02	18.3	32
34	0.2337	0.04289	0.492	11.4	5.28	9.68	25.2	34
36	0.1930	0.02927	0.589	16.7	7.74	14.2	36.9	36
38	0.1524	0.018241	0.946	26.9	12.4	22.8	59.2	38
40	0.1219	0.011675	1.48	42.0	19.2	35.5	92.5	40
42	0.1016	0.008107	2.13	60.4	27.9	51.2	133	42
44	0.0813	0.005189	3.32	94.4	43.7	80.0	208	44
46	0.0610	0.002919	5.91	168	77.6	142	370	46
48	0.0408	0.0012972	13.3	378	175	320	833	48
50	0.0254	0.0005067	34.0	967	447	819	2130	50

PREFERRED METRIC SIZES

These are given in three series: R10, R20 and R40. Where possible, the R10 series is to be used, the intermediate sizes occurring in R20 and R40 being reserved for special purposes. See British Standard BS3737 (1964). The table gives the diameters of wires in the R40 series expressed in mm; alternate values form the second choice, R20 series, alternate values of which give the first choice, R10 series.

R10, R20	0.020	0.040	0.080	0.160	0.315	0.63	1.25	2.5	5.0	10.0	20.0
	0.021	0.042	0.085	0.170	0.335	0.67	1.32	2.65	5.3	10.6	21.2
R20	0.022	0.045	0.090	0.180	0.355	0.71	1.40	2.8	5.6	11.2	22.4
	0.024	0.048	0.095	0.190	0.375	0.75	1.50	3.0	6.0	11.8	23.6
R10, R20	0.025	0.050	0.100	0.200	0.40	0.80	1.60	3.15	6.3	12.5	25.0
	0.026	0.053	0.106	0.212	0.425	0.85	1.70	3.35	6.7	13.2	
R20	0.028	0.056	0.112	0.224	0.45	0.90	1.80	3.55	7.1	14.0	
	0.030	0.060	0.118	0.236	0.475	0.95	1.90	3.75	7.5	15.0	
R10, R20	0.032	0.063	0.125	0.250	0.50	1.00	2.00	4.0	8.0	16.0	
	0.034	0.067	0.132	0.265	0.53	1.06	2.12	4.25	8.5	17.0	
R20	0.036	0.071	0.140	0.28	0.56	1.12	2.24	4.5	9.0	18.0	
	0.038	0.075	0.150	0.30	0.60	1.18	2.36	4.75	9.5	19.0	

METRIC WIRE SIZES AND WIRE RESISTANCES

Wire Dia., mm	Sectional Area mm ²	Copper Ohm per metre	Eureka Ohm per metre	German Silver Ohm per metre	Manganin Ohm per metre	Nichrome Ohm per metre	Wire Dia., mm
0.020	0.0003142	54.9	1560	721	1320	3440	0.020
0.025	0.0004909	35.1	998	461	845	2200	0.025
0.032	0.0008042	21.4	609	282	516	1340	0.032
0.040	0.001257	13.7	390	180	330	859	0.040
0.050	0.001963	8.79	250	115	211	550	0.050
0.063	0.003117	5.53	157	72.7	133	346	0.063
0.080	0.005027	3.43	97.5	45.1	82.6	215	0.080
0.100	0.007854	2.20	62.4	28.8	52.8	138	0.100
0.125	0.01227	1.41	39.9	18.5	33.8	88.7	0.125
0.160	0.02011	0.858	24.4	11.3	20.6	53.7	0.160
0.200	0.03142	0.549	15.6	7.21	13.2	34.4	0.200
0.250	0.04909	0.351	10.0	4.61	8.45	22.0	0.250
0.315	0.07793	0.221	6.29	2.91	5.33	13.9	0.315
0.400	0.1257	0.137	3.90	1.80	3.30	8.59	0.400
0.500	0.1963	0.0879	2.50	1.15	2.11	5.50	0.500

EMF OF STANDARD CELLS

Weston (Cadmium) cell (20°C)	= 1.0186 volts (absolute)
	= 1.0183 volts (international)
Clark cell (15°C)	= 1.4333 volts (absolute)
	= 1.4328 volts (international)

Temperature dependence

Weston cell

$$E_t = 1.0186 - 0.0000406(t-20) - 9.5 \times 10^{-7}(t-20)^2 \text{ absolute volts}$$

Clark cell

$$E_t = 1.4333 - 0.00119(t-15) - 7 \times 10^{-6}(t-15)^2 \text{ absolute volts}$$

APPROXIMATE EMFS OF CELLS

Bichromate	2	volts	Accumulator 2.0 volts (Ranges 1.85-2.2 volts)
Bunsen	1.9	"	Dry cell 1.5 volts
Daniell	1.08	"	Nickel-Cadmium 1.3 "
Grove	1.8	"	Nickel-Iron 1.4 "
Leclanché	1.46	"	Zinc-Silver oxide 1.8 "

RELATIVE PERMITTIVITIES (ϵ_r) OF VARIOUS SUBSTANCES AT ROOM TEMPERATURE (293 K)

Solid	ϵ_r	Liquid	ϵ_r	Gas	ϵ_r
Amber	2.8	Acetone	21.3	Air	1.000536
Ebonite	2.7-2.9	Benzene	2.28	Argon	1.000545
Glass	5-10	Carbon tetrachloride	2.17	Carbon dioxide	1.000986
Ice (268 K)	75	Castor oil	4.5	Carbon monoxide	1.000770
Marble	8.5	Ether	4.34	Deuterium	1.000270
Mica	5.7-6.7	Ethyl alcohol	25.7	Helium	1.00007
Paraffin wax	2.2-3	Glycerine	43	Hydrogen	1.00027
Perspex	3.5	Medicinal paraffin	2.2	Neon	1.000127
Polystyrene	2.55	Nitrobenzene	55.7	Nitrogen	1.000580
P.V.C.	4.5	Pentane	1.83	Oxygen	1.00053
Shellac	3-3.7	Silicon oil	2.2	Sulphur dioxide	1.00082
Sulphur	3.6-4.3	Turpentine	2.23	Water vapour	1.00060
Teflon	2.1	Water	80.37	(393 K)	

Values given in the table above refer to low frequencies, gases at 1 atmosphere pressure.

TEMPERATURE-EMF DATA FOR THERMOCOUPLES

The table gives the emf in millivolts for 'hot junction' temperatures from 0°-100°C. The 'cold junction' is maintained at 0°C.

Thermocouple	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
Platinum—Platinum (90%), Rhodium (10%)	0	0.06	0.11	0.17	0.23	0.30	0.36	0.43	0.50	0.57	0.64
Copper—Constantan	0	0.39	0.79	1.19	1.61	2.03	2.47	2.91	3.36	3.81	4.28
Iron—Constantan	0	0.52	1.05	1.58	2.12	2.66	3.20	3.75	4.30	4.85	5.40

MAGNETIC MASS SUSCEPTIBILITY, χ_m , (AT 293 K)

The mass susceptibility is given by the expression, $\chi_m = (\mu_r - 1)/\rho$; where μ_r is the relative permeability, and ρ the density of the specimen.

	χ_m/m^3		χ_m/m^3		χ_m/m^3
Aluminium	$\times 10^{-8}$ +0.82	Glass	$\times 10^{-8}$ -1.3	Oxygen	$\times 10^{-8}$ +133.6
Araldite	-0.63	Helium	-0.59	Perspex	-0.5
Carbon (graphite)	-4.4	Hydrogen	-2.49	Polyethylene	+0.2
Copper	-0.108	Lead chloride	-0.40	P.V.C.	-0.75
Copper sulphate	+7.7	Manganese chloride	+134	Sodium chloride	-0.63
Ebonite	+0.75	Manganese dioxide	+48.3	Sulphur	-0.62
Iron ammonium alum	+38.2	Manganese sulphate	+111	Sulphuric acid	-0.50
Ferric hydroxide	+197	Mercury	-0.21	Water	-0.90
Ferrous sulphate	+52.2	Nitrogen	-0.54		

MAGNETIC PROPERTIES OF SOME 'SOFT' MAGNETIC MATERIALS

Alloy	Maximum Relative Permeability μ_r	Coercive force $H_c/A \text{ m}^{-1}$	Energy loss per cycle $E/J \text{ m}^{-3}$	Resistivity $\rho/\text{ohm m}$	Saturation Induction B_s/T	Remarks
Iron, pure (total impurities <0.005%)	200,000	4.0	30	10	2.15	commercially impracticable
Mild steel	2,000	143	—500	10		
Silicon iron (1.25% Si)	6,100	67.6	220			isotropic
Silicon iron (4.25% Si)	9,000	23.9	70	60	2.0	isotropic
Silicon iron (3% Si)	40,000	12	30	47	2.0	anisotropic, (110) ·100
Silicon iron (3.8% Si)	1,400,000		<3			single crystal
Silicon iron (6.3% Si)	500,000		4.5			polycrystalline, magnetically annealed: brittle
78 Permalloy (Fe21.5%Ni78.5%)	100,000	4.0			1.08	
Superalloy (Fe16%Ni79%Mo5%)	1,000,000	0.16		60	0.79	
Ferrocube 3 (Mn-Zn ferrite)	1,500	0.8		10 ⁴	0.25	

PROPERTIES OF SOME COMMERCIAL PERMANENT MAGNET MATERIALS

Alloy	Compositon					Remanence B_r/T	Coercivity $H_c/A \text{ m}^{-1}$	Maximum $B \times H$ $(BH)_{max}/J \text{ m}^{-3}$	Comments
	Al	Ni	Co	Cu	Nb				
Alnico IV H	12	26	8	2		0.6	63,000		isotropic
Ticonal C	8	13.5	24	3	0.6	1.26	52,000	430	isotropic
Columax	8	13.5	24	3	0.5	1.35	64,000	64	columnar
Pt-Co alloy			23			0.45	210,000	300	ductile
Barium Ferrite $(\text{BaO} \cdot 6\text{Fe}_2\text{O}_3 \cdot \text{Co}_3\text{Sm})$						0.2	135,000	7,550	isotropic
Elongated single domain magnet (Fe50%Co50%)						0.85	600,000	140,000	mechanically weak
						0.905	80,000	40	

NOTE: The magnetic properties of materials depend critically on the manufacture and previous history of the specimen. The values in the tables above should therefore be taken as typical only.

17 Thermal Data

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DENSITY OF WATER (kg m^{-3}) AS A FUNCTION OF TEMPERATURE AT 1 ATMOSPHERE PRESSURE

Temperature $t/^\circ\text{C}$	0	2	4	6	8	10	12	14	16	18
0	999.87	999.97	1000	999.97	999.88	999.73	999.52	999.27	998.97	998.62
20	998.23	997.80	997.32	996.81	996.26	995.67	995.05	994.40	993.71	992.99
40	992.2	991.5	990.7	989.8	988.1	987.2	986.2	985.3	984.3	
60	983.2	982.2	981.1	980.1	978.9	977.8	976.7	975.5	974.3	973.1
80	971.8	970.6	969.3	968.0	966.7	965.3	964.0	962.6	961.2	959.8

Density at $100^\circ\text{C} = 958.4$; at $110^\circ\text{C} = 951$; at $150^\circ\text{C} = 917$; at $200^\circ\text{C} = 863 \text{ kg m}^{-3}$.

NOTE: water has a maximum density at 3.98°C (277.13 K).

SATURATED PRESSURE AND SPECIFIC VOLUME OF WATER VAPOUR

Temp. $t/^\circ\text{C}$	Temp. T/K	Saturated Vapour Pressure p_{sat}/MPa	Specific Volume $V_s/\text{m}^3 \text{ kg}^{-1}$	Temp. $t/^\circ\text{C}$	Temp. T/K	Saturated Vapour Pressure p_{sat}/MPa	Specific Volume $V_s/\text{m}^3 \text{ kg}^{-1}$
0	273.15	0.0006107	206.3	110	383	0.1433	1.2106
-0.01	273.16	0.0006112	206.1	120	393	0.1985	0.8920
1	274.15	0.0006165	192.6	130	403	0.2701	0.6685
2	275.15	0.0007054	179.9	140	413	0.3614	0.5088
3	276.15	0.0007575	168.2	150	423	0.4760	0.3926
4	277.15	0.0008129	157.3	160	433	0.6180	0.3068
5	278.15	0.0008719	147.1	170	443	0.7920	0.2426
8	281.15	0.0010721	121.0	180	453	1.0027	0.1938
10	283	0.0012277	106.4	190	463	1.2552	0.1563
15	288	0.001704	77.97	200	473	1.555	0.1271
20	293	0.002337	57.84	220	493	2.320	0.08601
25	298	0.003166	43.40	240	513	3.348	0.05964
30	303	0.004242	32.93	260	533	4.694	0.04212
40	313	0.007375	19.55	280	553	6.419	0.03011
50	323	0.01234	12.04	300	573	8.592	0.02162
60	333	0.01992	7.678	320	593	11.29	0.01544
70	343	0.03116	5.045	340	613	14.61	0.01078
80	353	0.04736	3.408	360	633	18.67	0.006967
90	363	0.07011	2.361	374.14	647.29	22.12	0.003155
100	373	0.101325	1.673				

*Triple point **Critical point

SPECIFIC HEAT CAPACITY OF WATER AT 1 ATMOSPHERE PRESSURE

Temperature $t/^\circ\text{C}$	Specific Heat Capacity $c_p/\text{J kg}^{-1} \text{ K}^{-1}$	Temperature $t/^\circ\text{C}$	Specific Heat Capacity $c_p/\text{J kg}^{-1} \text{ K}^{-1}$	Temperature $t/^\circ\text{C}$	Specific Heat Capacity $c_p/\text{J kg}^{-1} \text{ K}^{-1}$
0	4217.4	35	4177.9	70	4189.3
5	4201.9	40	4178.3	75	4192.5
10	4191.9	45	4179.2	80	4196.1
15	4185.5	50	4180.4	85	4200.2
20	4181.6	55	4182.1	90	4204.8
25	4179.3	60	4184.1	95	4210.0
30	4178.2	65	4186.5	100	4215.7

PROPERTIES OF MERCURY

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Temperature $t/^\circ\text{C}$	Vapour Pressure $p_{sat}/\text{mm Hg}$	Vapour Pressure p_{sat}/Pa	Density $\rho/\text{kg m}^{-3}$	Specific Heat Capacity $C_p/\text{J kg}^{-1} \text{ K}^{-1}$	Temperature T/K
-20	1.8×10^{-5}	2.4×10^{-3}	13 644.56	140.31	253
0	1.8×10^{-4}	2.4×10^{-2}	13 595.08	139.67	273
20	1.2×10^{-3}	0.16	13 545.88	139.08	293
40	6.1×10^{-3}	0.81	13 496.95	138.53	313
60	0.025	3.3	13 448.25	138.02	333
80	0.089	11.9	13 399.77	137.56	353
100	0.273	36.4	13 351.48	137.13	373
120	0.746	99.5	13 303.4	136.76	393
140	1.85	247	13 255.4	136.42	413
160	4.19	559	13 207.5	136.13	433
180	8.80	1170	13 159.7	135.88	453
200	17.28	2304	13 112.0	135.67	473

RELATIVE HUMIDITIES FROM WET- AND DRY-BULB THERMOMETERS (exposed in Standard Screen)

The relative humidity is defined as the ratio, expressed as a percentage, of the actual vapour pressure to the saturation vapour pressure at the temperature of the dry bulb. The dry bulb thermometer is an ordinary thermometer; the 'wet-bulb' thermometer is similar in design and has its bulb enclosed in a wick, the other end of which dips into water. By capillary action the thermometer bulb is wet and under the usually encountered conditions evaporation of the water lowers the temperature of the bulb. The difference in reading of the two thermometers is the 'Depression of the wet bulb'. The tables below give relative humidities for various values of the dry bulb temperature and the depression. Temperatures are in degrees Celsius.

Depression of Wet Bulb $^{\circ}\text{C}$	Dry Bulb Temperature/ $^{\circ}\text{C}$															
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
0.5	91	92	93	93	94	94	95	95	95	96	96	96	96	96	96	96
1.0	81	84	85	86	87	88	89	90	91	91	92	92	93	93	93	93
1.5	73	76	78	80	81	82	83	85	86	87	87	88	88	89	89	89
2.0	64	68	71	73	75	77	78	79	81	82	83	84	85	85	86	86
2.5	55	61	64	66	69	71	73	75	76	77	78	80	80	81	82	83
3.0	46	52	57	60	63	66	68	70	71	73	74	76	77	78	78	79
3.5	38	45	49	54	57	60	63	65	67	69	70	72	73	74	75	76
4.0	29	37	43	48	51	55	58	60	63	65	66	68	69	71	72	73
4.5	21	29	36	41	46	50	53	56	58	61	62	64	66	67	69	70
5.0	13	22	29	35	40	44	48	51	54	57	59	61	62	64	65	67
5.5	5	14	22	29	35	39	43	47	50	53	55	57	59	61	62	64
6.0	7	16	24	29	34	39	42	46	49	51	54	56	58	59	61	61
6.5	9	17	24	34	38	42	45	48	50	53	54	56	58	59	61	61
7.0	11	19	24	34	38	41	44	47	49	51	53	55	57	59	61	61
7.5	14	20	26	34	38	41	44	46	49	51	53	55	57	59	61	61
8.0	15	21	26	30	34	37	40	43	46	49	51	53	55	57	59	59
8.5	16	22	26	30	34	37	40	43	46	49	51	53	55	57	59	59
9.0	16	22	26	30	34	37	40	43	46	49	51	53	55	57	59	59
9.5	17	23	27	31	34	37	40	43	46	49	51	53	55	57	59	59
10.0	15	20	24	28	31	34	37	40	43	46	49	51	53	55	57	59

INTERNATIONAL PRACTICAL TEMPERATURE SCALE 1968

Boiling and freezing temperatures listed below refer to standard atmospheric pressure of 101325 Pa except where stated otherwise.

	<i>t/°C</i>	<i>T/K</i>
<i>Primary Reference Temperatures</i>		
Equilibrium Hydrogen, triple point	-259.34	13.81
Equilibrium Hydrogen, boiling temperature at pressure 33330.6 Nm ⁻² (25 mm Hg)	-256.108	17.042
Equilibrium Hydrogen, boiling temperature	-252.87	20.28
Neon, boiling temperature	-246.048	27.102
Oxygen, triple point	-218.789	54.361
Oxygen, boiling temperature	-182.962	90.188
Water, triple point	0.01	273.16
Water, boiling temperature	100.00	373.15
Zinc, freezing temperature	419.58	692.73
Silver, freezing temperature	961.93	1235.08
Gold, freezing temperature	1064.43	1337.58
<i>Secondary Reference Temperatures</i>		
Normal Hydrogen, triple point	-259.194	13.956
Normal Hydrogen, boiling temperature	-252.753	20.397
Neon, triple point	-248.595	24.555
Nitrogen, triple point	-210.002	63.148
Nitrogen, boiling temperature	-195.802	77.348
Carbon dioxide, sublimation point	-78.476	194.674
Mercury, freezing temperature	-38.862	234.288
Water, ice point	0	273.15
Phenoxybenzene, triple point	26.87	300.02
Benzoic acid, triple point	122.37	395.52
Indium, freezing temperature	156.634	429.784
Bismuth, freezing temperature	271.442	544.592
Cadmium, freezing temperature	321.108	594.258
Lead, freezing temperature	327.502	600.652
Mercury, boiling temperature	356.66	629.81
Sulphur, boiling temperature	444.674	717.824
Copper-aluminium eutectic, freezing temperature	548.23	821.38
Antimony, freezing temperature	630.47	903.89
Aluminium, freezing temperature	660.37	933.52
Copper, freezing temperature	1084.5	1357.6
Nickel, freezing temperature	1455	1728
Cobalt, freezing temperature	1494	1767
Palladium, freezing temperature	1554	1827
Platinum, freezing temperature	1772	2045
Rhodium, freezing temperature	1963	2236
Iridium, freezing temperature	2447	2720
Tungsten, freezing temperature	3387	3660

18 Optical Data and the Electromagnetic Spectrum 71

REFRACTIVE INDICES (*n*) AGAINST AIR, FOR THE MEAN SODIUM D LINE (589.3 nm)

Calcite (ord)	1.658	Polystyrene	1.591
Calcite (extr)	1.486	Potassium alum	1.456
Canada balsam	1.530	Potassium iodide	1.667
Diamond	2.417	Quartz (ord)	1.544
Felspar	1.52	Quartz (extr)	1.553
Fluorspar	1.434	Rock salt (NaCl)	1.544
Glass, crown	1.48-1.61	Ruby	1.76
Glass, flint	1.53-1.96	Silver bromide	2.25
Ice	1.31	Sodium fluoride	1.326
Perspex	1.495	Sylvine (KCl)	1.490

WAVELENGTHS OF IMPORTANT SPECTRAL LINES IN AIR AT 15°C AND 1 ATMOSPHERE PRESSURE. UNITS, nm (10⁻⁹ m)

Spectral line	Wavelength λ/nm	Spectral line	Wavelength λ/nm
K red	766.5	Fe and Ca green (E)	527.0
O red A	759.4	Mg green (b ₁)	518.3
O red B	687.0	Mg green (b ₂)	517.3
Li red	670.8	Mg green (b ₃)	516.7
Hα red (c)	656.3	*Cd green	508.582
*Cd red	643.84696	Hβ blue-green (F)	486.1
Li orange	610.4	*Cd blue	479.991
Na orange (D ₁)	589.59	Sr blue	460.7
Na orange (D ₂)	589.00	Li blue	460.3
He yellow (D ₃)	587.56	Hg blue	435.8
Hg yellow	579.0	Hy blue (G ₁)	434.0
Hg yellow	577.0	Fe and Ca blue (G)	430.8
Hg green	546.1	Ca blue (g)	422.7
Tl green	535.0	Hg and K violet	404.7

*Accepted standard lines

THE ELECTROMAGNETIC SPECTRUM

Type of radiation	Frequency v/Hz	Wavelength λ/m	Wave No. σ/m^{-1}	Quantum Energy
gamma rays	10^{24}	10^{-16}	10^{16}	12 400 MeV
	10^{23}	10^{-15}	10^{15}	1 240 MeV
	10^{22}	10^{-14}	10^{14}	124 MeV
	10^{21}	10^{-13}	10^{13}	12.4 MeV
	10^{20}	10^{-12}	10^{12}	1.24 MeV
	10^{19}	10^{-11}	10^{11}	124 keV
	10^{18}	10^{-10}	10^{10}	12.4 keV
	10^{17}	10^{-9}	10^9	1.24 keV
	10^{16}	10^{-8}	10^8	124 eV
	10^{15}	10^{-7}	10^7	12.4 eV
Violet $\lambda \sim 4 \times 10^{-7}\text{ m}$	Ultra-violet	10^{15}		
Visible Spectrum				
Red	Infra-red			
Microwaves, radar	$\lambda \sim 7 \times 10^{-7}\text{ m}$	10^{-6}	10^6	
	10^{14}	10^{-5}	10^5	
	10^{13}	10^{-4}	10^4	
	10^{12}	10^{-3}	10^3	
	10^{11}	10^{-2}	10^2	
	10^{10}	10^{-1}	10^1	
	10^9	1	1	
	10^8	10^{-1}	10^{-1}	
	10^7	10^2	10^{-2}	
	10^6	10^3	10^{-3}	
Short waves				
Long waves	10^5	10^4	10^{-4}	

19 Acoustic Data

SPEED OF SOUND AT ROOM TEMPERATURE

Substance	Temp. $^\circ\text{C}$	Speed m s^{-1}	Substance	Speed m s^{-1}
Air	0	331.3	Aluminium	5100
Hydrogen	0	1284	Brass	3500
Oxygen	0	316	Copper	3800
Water	25	1498	Iron	5000
Oak (along fibre)	15	3850	Lead	1200
Glass	20	5000	Mercury	1452

N.B.—The velocity of sound can vary according to the crystalline state and previous history of the specimen. The values quoted for solids are for longitudinal waves in thin specimens.

LOUDNESS OF SOUNDS

Intensity in terms of threshold-intensity I/I_{min}	Intensity I/dB	Loudness L/phon
1	0	Threshold of hearing
10	10 (1 bel)	Virtual silence
10^1	20	Quiet room
10^2	30	Watch ticking at 1 m
10^3	40	Quiet street
10^4	50	Quiet conversation
10^5	60	Quiet motor at 1 m
10^6	70	Loud conversation
10^7	80	Door slamming
10^8	90	Busy typing room
10^{10}	100	Near loud motor horn
10^{11}	110	Pneumatic drill
10^{12}	120	Near aeroplane engine
10^{13}	130	Threshold of pain

Limits of Audibility—Between 30 and 30 000 Hz (approximately).

MUSIC

The consonant frequency intervals.

Name	Octave	Fifth	Fourth	Major Third	Major Sixth	Minor Third	Minor Sixth
Frequency Ratio	1:2	2:3	3:4	4:5	3:5	5:6	3:8

Musical Scales—Vibration Ratios

Basic ^a	C	D	E	F	G	A	B	C
Scale	24	27	30	32	36	40	45	48
Intervals	1.000	1.125	1.250	1.333	1.300	1.667	1.875	2.000

^aThe Basic Scale is frequently referred to as the Natural or Diatonic Scale.

The vibration-numbers in the Basic Scale must bear the given ratios to each other, but their absolute values are matter of convention.

The London International Conference of May 1939 agreed that the international standard of concert pitch should be based on 440Hz for the treble A, i.e. 264 for the 'Middle C'.

In the **EQUALLY TEMPERED SCALE** the octaves remain as before, but 11 notes are introduced between them, the intervals being made equal and each $12^{\text{th}}\sqrt{2}$, i.e. 1.0595, say 1.06 (approx.).

The following is such an equally tempered chromatic scale based on 440Hz as the treble A:

	Frequency v/Hz	Frequency v/Hz	Frequency v/Hz
C'	261.6	F	349.2
C#	277.2	F#	370.0
D	293.7	G	392.0
D#	311.1	G#	415.3
E	329.6		
		A	440.0
		A#	466.2
		B	493.9
		C'	523.2

ABSORPTION COEFFICIENTS OF BUILDING MATERIALS; UNIT, SABINE

	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Acoustic plaster, 13 mm	0.15	0.20	0.35	0.60	0.60	0.50
Acoustic tiles, 20 mm	0.10	0.35	0.70	0.75	0.65	0.50
Brick, unglazed	0.03	0.03	0.03	0.04	0.05	0.07
Carpet, on concrete	0.02	0.06	0.14	0.37	0.60	0.65
Carpet with foam underlay	0.08	0.24	0.57	0.69	0.71	0.73
Curtain, heavy velour	0.14	0.35	0.55	0.72	0.70	0.65
Linoleum, on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Glass, heavy plate	0.18	0.06	0.04	0.03	0.02	0.02
Glass, window	0.35	0.25	0.18	0.12	0.07	0.04
Plaster	0.013	0.015	0.02	0.03	0.04	0.05
Plywood panelling, 10 mm	0.28	0.22	0.17	0.09	0.10	0.11
Polystyrene, expanded, 13 mm	0.05	0.15	0.40	0.35	0.20	0.20
Polyurethane fcam, 50 mm	0.25	0.50	0.85	0.95	0.90	0.90
Tiles, glazed	0.01	0.01	0.01	0.01	0.02	0.02
Wood parquet	0.04	0.04	0.07	0.06	0.06	0.07

20 Astronomical Data

TIME

1 mean solar second = $\frac{1}{86400}$ of a mean solar day.

1 sidereal day = 86 164.090 6 mean solar seconds.

1 tropical (civil) year = 365.242 mean solar days = $3 \cdot 155\ 692\ 597\ 47 \times 10^7$ s

1 sidereal year = 365.256 mean solar days.

1 mean synodical or lunar month = 29.531 mean solar days.

N.B.—Centuries are not leap years unless divisible by 400.

DISTANCE

1 Astronomical Unit (AU) = mean sun-earth distance = $1 \cdot 495\ 985(5) \times 10^{11}$ m

1 Parsec (pc) = $3 \cdot 085\ 6(1) \times 10^{16}$ m = $2 \cdot 062\ 648 \times 10^9$ AU = 3.261 5 ly

1 Light year (ly) = $9 \cdot 460\ 5 \times 10^{15}$ m = $6 \cdot 324 \times 10^4$ AU = 0.3066 pc

THE SUN

Radius = $6 \cdot 960 \times 10^8$ m = $4 \cdot 326 \times 10^3$ miles

Surface area = $6 \cdot 087 \times 10^{18}$ m²

Volume = $1 \cdot 412 \times 10^{27}$ m³

Mass = $1 \cdot 99 \times 10^{30}$ kg

Mean density = 1409 kg m⁻³

Rate of energy production = $3 \cdot 90 \times 10^{26}$ W

Gravity at surface = 274 m s⁻²

Moment of inertia = $6 \cdot 0 \times 10^{46}$ kg m²

Escape velocity at surface = 618 km s⁻¹

Sidereal period of rotation = 25.38 days

Period of rotation with respect to the earth = 27.28 days } latitude 16°

THE MOON

Radius = 1738 km = 1080 miles

Surface area = $3 \cdot 796 \times 10^{13}$ m²

Volume = $2 \cdot 199 \times 10^{19}$ m³

Mass = $7 \cdot 349 \times 10^{22}$ kg = $1/81.4$ × mass of earth

Mean density = 3340 kg m⁻³

Sidereal period of moon about earth = 27.32 mean solar days

Mean synodical or lunar month = 29.531 mean solar days

Mean distance from the earth = $3 \cdot 844 \times 10^8$ m = $2 \cdot 39 \times 10^5$ miles

Surface area of the moon at some time visible from the earth = 59%

Gravity at surface = $1 \cdot 62$ m s⁻²

Moment of inertia = $8 \cdot 8 \times 10^{38}$ kg m²

Escape velocity at surface = $2 \cdot 38$ km s⁻¹

Body	Equatorial radius R/m	Mass M/kg	Density $\rho/kg\ m^{-3}$	Distance from Sun. d/m	Surface gravity $g/m\ s^{-2}$	Eccentricity of orbit e	Inclination to ecliptic i/\circ	No. of satellites N	Sidereal period T_s	Rotational period T_r
Sun	6.960×10^3	1.989×10^{30}	1409	1.496×10^{11}	1.62	—	0.055	5.144	—	25.38d
Moon	1.738×10^6	7.353×10^{12}	3340	1.496×10^{11}	274	0	—	—	27.32d	27.32d
Mercury	2.42×10^6	3.301×10^{23}	5420	5.791×10^{10}	3.76	0	0.2056	7.004	0	87.97d
Venus	6.085×10^6	4.869×10^{24}	5250	1.082×10^{11}	8.77	0	0.0068	3.394	0	224.7d
Earth	6.378×10^6	5.978×10^{24}	5510	1.496×10^{11}	9.81	0.0034	0.0167	0	1	365.3d
Mars	3.375×10^6	6.420×10^{23}	3960	2.279×10^{11}	3.80	0.007	0.0934	1.850	2	687d
Jupiter	7.14×10^7	1.899×10^{27}	1330	7.783×10^{11}	24.9	0.062	0.0481	1.306	12	11.86a
Saturn	6.04×10^7	5.685×10^{26}	680	1.427×10^{12}	10.4	0.096	0.0533	2.489	10	29.46a
Uranus	2.36×10^7	8.686×10^{25}	1600	2.869×10^{12}	10.4	0.06	0.0507	0.773	5	84.02a
Neptune	2.23×10^7	1.025×10^{26}	1650	4.498×10^{12}	13.8	0.02	0.0040	1.773	2	164.8a
Pluto	3×10^6	5×10^{23}	3000	5.900×10^{12}	4	—	0.2533	17.142	0	248a
										6.3d

Notes: Ellipticity of a planet is defined by $(R_e - R_p)/R_e$, where R_e is the equatorial radius and R_p is the polar radius. The sidereal period of a planet is the time to move once round its orbit. Periods are measured in hours (h), days (d) or years (a).

THE SCALE OF VISUAL MAGNITUDE

This scale is used to indicate the brightness of a star as observed by the human eye. A visual magnitude of 6 is just visible to the human eye, and brighter stars are indicated by smaller visual magnitudes on a logarithmic scale. A change in visual magnitude of 1 unit indicates a change in the brightness of the star by a factor $\sqrt[5]{100} = 2.512$. Thus a star of magnitude 1 is 100 times brighter than a star of magnitude 6 and a star of magnitude -1 is 2.512 times brighter than a star of magnitude 0.

THE BRIGHTEST STARS in decreasing order of brightness

Star	Visual Magnitude	Distance, $d/10^{15}m$	Distance $d/\text{light years}$
α Canis Majoris (Sirius)	-1.6	82	8.7
α Carinae (Canopus)	-0.9	1700	180
α Centauri (Rigel Kent)	0.1	41	4.3
α Lyrae (Vega)	0.1	251	27
α Boötis (Arcturus)	0.2	340	36
α Aurigae (Capella)	0.2	420	44
β Orionis (Rigel)	0.3	11 000	1200
α Canis Minoris (Procyon)	0.5	107	11
α Eridani (Achernar)	0.6	1300	140
β Centauri (Hadar)	0.9	1900	200

APPROXIMATE GALACTIC DISTANCES

including Baade's correction
(M = Messier Catalogue No. N.G.C. = new general catalogue No.)

Great Nebula in Andromeda

(M31, N.G.C. 224)	22×10^5 light years	$= 210 \times 10^{20} m$
Nebula in Andromeda (M32)	15×10^5	$= 140 \times 10^{20} m$
Nebula in Andromeda (N.G.C. 205)	15×10^5	$= 140 \times 10^{20} m$
Nebula in Triangulum (M33)	15×10^5	$= 140 \times 10^{20} m$
Large Magellanic Cloud (in Dorado)	1.4×10^5	$= 13 \times 10^{20} m$
Small Magellanic Cloud (in Toucan)	1.5×10^5	$= 14 \times 10^{20} m$
Crab Nebula (N.G.C. 1952)	6×10^3	$= 0.6 \times 10^{20} m$

THE EARTH

Polar radius = 6356.8 km
 Equatorial radius = 6378.2 km
 Mean radius = 6371 km = 3960 miles
 Surface area = $5.101 \times 10^{14} \text{ m}^2$
 Volume = $1.083 \times 10^{21} \text{ m}^3$

Mass = $5.977 \times 10^{24} \text{ kg}$
 Mean density = 5517 kg m^{-3}

Mean distance to the sun (AU) = $1.496 \times 10^{11} \text{ m} = 9.2868 \times 10^7 \text{ miles}$
 Distance to sun at perihelion = $1.471 \times 10^{11} \text{ m} = 9.136 \times 10^7 \text{ miles}$
 Distance to sun at aphelion = $1.521 \times 10^{11} \text{ m} = 9.447 \times 10^7 \text{ miles}$
 Gravity at surface = 9.80665 m s^{-2} (standard)

Moment of inertia about axis of rotation = $8.04 \times 10^{37} \text{ kg m}^2$

Escape velocity at surface = 11.2 km s^{-1}

Rotational velocity at equator = 465 m s^{-1}

Mean Velocity in its orbit about the sun = 29.78 km s^{-1}

Solar constant = solar energy incident on unit area normal to the sun's rays at the earth's mean distance, per unit time = $1400 \text{ J m}^{-2} \text{ s}^{-1}$

1° of latitude at equator = $110.5 \text{ km} = 68.70 \text{ miles}$.

1° of latitude at poles = $111.7 \text{ m} = 69.41 \text{ miles}$

1° of longitude at equator = $111.3 \text{ km} = 69.17 \text{ miles}$.

Inclination of equator to ecliptic = $23^\circ 27'$.

Greatest height (Mt. Everest) = $8847.7 \text{ m} = 29.028 \text{ ft}$ (1954 Indian Survey).

Greatest depth (Marianas Trench) = $11.033 \text{ m} = 35.960 \text{ ft}$.

Land area = $148.8 \times 10^6 \text{ km}^2 = 5.747 \times 10^7 \text{ miles}^2$.

Ocean area = $361.3 \times 10^6 \text{ km}^2 = 13.95 \times 10^7 \text{ miles}^2$.

COMPOSITION OF THE ATMOSPHERE

The composition of dry air is remarkably constant all over the globe and throughout the entire troposphere. The proportions by volume of the various components are given below (after A. F. Paneth, 1939, 1952).

Substance	% by volume	Substance	% by volume
N ₂	78.09	CH ₄	2.0×10^{-4}
O ₂	20.95	Kr	1×10^{-4}
Ar	0.93	H ₂	5×10^{-5}
³⁸ CO ₂	0.03	N ₂ O	5×10^{-5}
Ne	1.8×10^{-3}	Xe	9×10^{-6}
He	5.2×10^{-4}	Rn	6×10^{-18}

*This varies somewhat near towns and industrial areas.

THE ICAO STANDARD ATMOSPHERE

The International Civil Aviation Organization have defined a standard atmosphere which is an attempt to represent atmospheric conditions in temperate latitudes. At sea level, standard pressure and acceleration of gravity are assumed for a temperature of 288 K (15°C). The air is assumed to be a perfect gas of fixed composition.

Sea level properties of the ICAO atmosphere

Collision frequency	$6.9204 \times 10^9 \text{ s}^{-1}$	Pressure	$1.01325 \times 10^5 \text{ Pa}$
Density	1.225 kg m^{-3}	Scale height	$8.4344 \times 10^3 \text{ m}$
Gravitational acceleration	9.80665 m s^{-2}	Speed of sound	340.29 m s^{-1}
Kinematic viscosity	$1.4607 \times 10^{-5} \text{ m}^2 \text{ s}^{-1}$	Temperature	288.15 K
Mean free path	$6.6317 \times 10^{-8} \text{ m}$	Thermal conductivity	$2.5339 \times 10^{-2} \text{ W m}^{-1} \text{ K}^{-1}$
Molar volume	$2.3645 \times 10^{-2} \text{ m}^3 \text{ mol}^{-1}$		
Molecular weight	28.966	Viscosity	$1.7894 \times 10^{-5} \text{ kg m}^{-1} \text{ s}^{-1}$
Number density	$2.5475 \times 10^{23} \text{ m}^{-3}$		
Particle speed	$4.5894 \times 10^3 \text{ m s}^{-1}$		

Variation of pressure, density and temperature with height

Geometric Height h/m	Pressure p/Pa	Density ρ/kg m ⁻³	Temp. T/K	Geometric Height h/m	Pressure p/Pa	Density ρ/kg m ⁻³	Temp. T/K
-250	104365	1.2547	289.775	6000	47217.6	0.66011	249.187
0	101325	1.2250	288.150	7000	41105.2	0.59002	242.700
+250	98357.6	1.1959	286.525	8000	35651.6	0.52579	236.215
500	95461.2	1.1673	284.900	9000	30800.7	0.46706	229.733
750	92634.6	1.1392	283.276	10000	26499.9	0.41351	223.252
1000	89876.2	1.1117	281.651	15000	12111.8	0.19475	216.650
1500	84559.6	1.0581	278.402	20000	5529.3	0.08891	216.650
2000	79501.4	1.0066	275.154	25000	2594.2	0.04008	221.552
2500	74691.7	0.95695	271.906	30000	1197.0	0.01841	226.509
3000	70121.1	0.90925	268.659	32000	889.1	0.01355	228.490
3500	65780.3	0.86340	265.413	50000	80.96	1.041×10^{-3}	271
4000	61660.4	0.81935	262.166	100000	3.095×10^{-3}	5.062×10^{-7}	213
5000	54048.2	0.73643	255.676	200000	8.806×10^{-5}	2.56×10^{-10}	1198

NOTE: the above table is reproduced by permission of the International Civil Aviation Organization, Montreal. The last three sets of values in this table are taken from the COSPAR International Reference Atmosphere, 1965 (CIRA 1965) by permission of the publishers, North Holland Publishing Co., Amsterdam.

Principal Elements in Earth's Crust (% by mass)

Oxygen 49.13%, Silicon 26.0%, Aluminium 7.45%, Iron 4.2%, Calcium 3.25%, Sodium 2.4%, Potassium 2.35%, Magnesium 2.35%, Hydrogen 1%. All others 1.87%.

Principal Elements in the Hydrosphere (% by mass)

Oxygen 85.89%, Hydrogen 10.82%, Chlorine 1.90%, Sodium 1.06%. All others 0.33%.

ACCELERATION OF GRAVITY (g)

At latitude, λ , and height, h (measured in metres), above sea-level, the acceleration of gravity is given by the expression:

$$\text{g/m s}^{-2} = 9.80616 - 0.025928 \cos 2\lambda + 0.000069 \cos^2 2\lambda - 0.000003 h$$

Geophysical data for various places of importance.

In the following tables, values of the acceleration of gravity and the length of the seconds pendulum are calculated using the formulae above. In addition, magnetic data, calculated for the year 1970 are included. These have been obtained from the International Reference Geomagnetic Field and excluding local variations should not be in error by more than 1%. Declination is positive Eastward and Angle of Dip positive downwards. Magnetic Induction for geophysical fields is often measured in gammas. Where 1 gamma = 10^{-8} Tesla or 1 gamma = 1 nT.

Location	Position	Acceleration of Gravity g/m s^{-2}	Length of Seconds Pendulum l/m	Declination D°	Horizontal Component of Earth's Magnetic Field H/Am^{-1}	Horizontal Component of Earth's Magnetic Induction B_H/nT	Angle of Dip I°
Equator	0°N	9.78030	0.99094				
Madras	13°5'N 80°18'E	9.78281	0.99120	-2.23	32.4	40660	9.1
Calcutta	22°33'N 88°21'E	9.7882	0.99175	-6.82	31.2	39200	29.9
Sydney	33°55'S 151°10'E	9.7968	0.99262	11.9	20.2	25380	-64.1
Capetown	33°56'S 18°28'E	9.7966	0.99260	-24.6	9.86	12390	-65.1
Tokyo	35°40'N 139°45'E	9.79801	0.99275	-6.4	24.3	30510	48.3
New York	40°40'N 73°50'W	9.80267	0.99322	-11.6	14.6	18420	71.0
Paris	48°52'N 2°20'E	9.80943	0.99390	-5.5	16.0	20140	64.7
London	51°25'N 0°20'W	9.81183	0.99415	-7.0	15.0	18820	66.8
Edinburgh	55°57'N 3°13'W	9.8158	0.99455	-9.4	13.2	16620	70.1
Leningrad	59°55'N 30°25'E	9.81929	0.99490	7.0	12.1	15180	72.8
Nth Pole	90°0'N	9.8322	0.99621				

TABLE OF ENERGY EQUIVALENTS

Energy associated with:	Basic equation	J	eV	calories	kWh
1 Joule (J)		1	6.242×10^{-16}	0.2389	2.778×10^{-7}
1 eV	$E = eV$	1.602×10^{-19}	1	3.828×10^{-20}	4.430×10^{-26}
1 calorie		4.186	2.613×10^{-17}	1	1.163×10^{-6}
1 kilowatt-hour (kWh)		3.600×10^6	2.247×10^{35}	8.600×10^5	1
1 kilogram (kg)	$E = mc^2$	8.988×10^{16}	5.610×10^{35}	2.147×10^{16}	2.497×10^{10}
1 electron mass (m_e)	$E = mc^2$	8.187×10^{-10}	5.110×10^5	1.956×10^{-16}	2.274×10^{-20}
1 unified mass unit (u)	$E = mc^2$	1.492×10^{-10}	9.313×10^6	3.564×10^{-11}	4.144×10^{-19}
1 Hertz (Hz)	$E = hv$	6.626×10^{-34}	4.136×10^{-13}	1.583×10^{-16}	1.841×10^{-40}
1 reciprocal metre	$E = hc/\lambda$	1.986×10^{-25}	1.240×10^{-6}	4.745×10^{-26}	5.517×10^{-33}
1 Kelvin (K)	$E = kT$	1.381×10^{-23}	8.620×10^{-3}	3.299×10^{-24}	3.836×10^{-30}

22 Units of Energy and Energy Equivalents

There are various relationships, basic to physics, which introduce the energy associated with a system. Of these, the following are of especial importance:

$$\text{Einstein's equation, } E = mc^2,$$

$$\text{Planck's equation, } E = hv,$$

$$\text{Boltzmann's equation, } E = kT.$$

Partly as a result of the importance of the concept of energy, there are many different units in which it is measured. The cgs unit is the erg, the SI unit is the Joule, while in atomic and nuclear physics, it is always measured in electron volts (eV). Other units in common use are the calorie and the kilowatt hour. The table below is based on the equations above and may be used for converting most of the commonly encountered energy units. It gives equivalent quantities in horizontal lines. Thus $1 \text{ kg} = 8.988 \times 10^{16} \text{ J} = 1.097 \times 10^{30}$ electron masses etc.

TABLE OF ENERGY EQUIVALENTS (CONT.)

kg	me	u	Hz	m^{-1}	K
1.113×10^{-17}	1.221×10^{13}	6.702×10^9	1.509×10^{33}	5.034×10^{14}	7.244×10^{21}
1.783×10^{-36}	1.936×10^{-6}	1.074×10^{-9}	2.418×10^{14}	8.065×10^8	1.180×10^4
4.658×10^{-17}	5.110×10^{13}	2.805×10^{10}	6.316×10^{35}	2.107×10^{25}	3.032×10^{23}
4.007×10^{-11}	4.396×10^{19}	2.413×10^{16}	5.432×10^{39}	1.812×10^{51}	2.608×10^{39}
1	1.097×10^{30}	6.024×10^{26}	1.356×10^{50}	4.525×10^{41}	6.511×10^{39}
9.112×10^{-31}	1	5.487×10^{-4}	1.235×10^{30}	4.121×10^{11}	5.931×10^9
1.661×10^{-27}	1.822×10^3	1	2.251×10^{23}	7.511×10^{14}	1.081×10^{13}
7.375×10^{-31}	8.090×10^{21}	4.441×10^{-24}	1	3.336×10^{-9}	4.800×10^{-11}
2.210×10^{-42}	2.423×10^{-12}	1.331×10^{-19}	2.997×10^8	1	1.439×10^{-2}
1.537×10^{-40}	1.686×10^{-16}	9.255×10^{-16}	2.084×10^{10}	6.952×10^1	1

The most common unit of radioactivity is the Curie (Ci). Originally defined as the volume of radon gas in equilibrium with 1 g of radium, it has since become associated with the number of disintegrations occurring per second in 1 g of radium free from its daughter products viz. 3.7×10^{10} disintegrations per second. In modern usage, the curie has been redefined to agree with this result, and other units have been introduced as given below.

One curie (Ci) of any radioactive substance is that quantity in which 3.7×10^{10} atoms disintegrate per second. The millicurie (mCi) and microcurie (μCi) are in common usage.

The rutherford is the unit of activity corresponding to 10^6 disintegrations per second. Thus 37 rutherford = 1 mCi.

The roentgen (r) was originally suggested as a unit of radiation and has become of universal use in defining the quantities of X-rays or γ -rays present. In 1937, the Fifth International Congress of Radiobiology recommended the following definition:

The roentgen is that quantity of X- or γ -radiation such that the associated corpuscular emission per 0.001293 g of dry air produces, in air, ions carrying 1 esu of quantity of electricity of either sign. (N.B. this mass of air occupies 1 cm³ at STP).

Dose rates are often measured in units of roentgen hour⁻¹ or milliroentgen hour⁻¹ (mr h⁻¹).

The rad is defined as the absorbed dose of radiation when 1 g of material absorbs 100 ergs of energy. 1 rad = 10^{-2} J kg⁻¹.

The roentgen equivalent man (rem) is the unit Dose Equivalent used in Radiation Protection. The Dose Equivalent is the product of the Absorbed Dose (measured in rad) and the quality factor Q , of the radiation. The value of Q indicates how damaging the particular radiation is, compared with 200 keV X-rays. Thus, low energy β -rays have $Q = 1.7$, while neutrons impinging on the eye have $Q = 30$.

A useful, but approximate formula for calculation of dose rates from γ -ray point sources is

$$\text{Dose rate (r hr}^{-1}\text{)} \simeq (5000 C E)/d^2$$

where C is the activity of the source in curies, E the energy of the γ -ray emitted in MeV and d is the distance from the source in cm. If more than one γ -ray is emitted, the total dose rate is the sum of the individual dose rates.

The naturally radioactive materials with the exception of a few isotopes, e.g. ^{40}K are the heavy elements of atomic number $Z > 80$. Three 'families' are known in which one substance decays to another which in turn continues the process until a stable material (lead) is attained. The decay process involves the emission of an electron (β -particle) or an α -particle from the nucleus. In the former case, the mass number, A , remains unchanged while Z increases by unity, while the latter emission involves a decrease in A of four and a decrease in Z of two as the α -particle is the helium nucleus. In any one 'family' the mass numbers alter in steps of four only. In the Thorium family each value of A can be described by the number ($4n$), the Uranium family by ($4n+2$) and the Actinium family by ($4n+3$). The apparently missing family ($4n+1$) has been found

as a result of the artificial production of heavy isotopes. It does not appear naturally because the longest half life is short compared with the age of the earth.

The law of radioactive decay

All radioactive substances transform at a rate which is proportional to the number of atoms present. If there are N_0 atoms present at the zero of time, then at time, t , there are N_t , where

$$N_t = N_0 \exp -(\lambda t)$$

Here, λ , is a constant for the particular type of atom considered and is known as the transformation constant. The rate at which an atom decays is often measured in terms of the mean lifetime of the atom, τ , or the half-value period, $T_{1/2}$, which is often abbreviated to the half-life. The relation between these constants is:

$$\tau = 1/\lambda = T_{1/2} \log 2$$

For values of the half-value periods of important isotopes see section 27, Table of Isotopes, P87ff.

24 Properties of Inorganic Compounds

In the following table, properties refer to room temperature, 293 K. Enthalpies of Formation refer to the substance in the crystalline (c), liquid (lq), or gaseous (g) states at 293 K. A negative value indicates that heat is evolved in the formation of the compound, while a positive value indicates absorption of heat. The following abbreviations are used:

bl.	black	effl.	efflorescent	s.	sublimes
col.	colourless	ex.	explodes	tetr.	tetragonal
crys.	crystals	gn.	green	trig.	trigonal
cub.	cubic	hex.	hexagonal	visc.	viscous
d.	dissociates	mono.	monoclinic	w.	white
delq.	deliquescent	rh.	rhombic	yel.	yellow

Formula	Molecular Weight M/g mol ⁻¹	Melting Point T _m /K	Boiling Point T _b /K	Density ρ/kg m ⁻³	Refractive Index n	Enthalpy of Formation ΔH ^θ /kJ mol ⁻¹	Description
Al	Al ₂ O ₃	101.96	2290	3250	3965	1.768	-1670 c
Ag	AgBr	187.78	705	1600 (d)	6473	2.252	-99.5 c
	AgCl	143.32	728	1820	5560	2.071	w. cub
	AgNO ₃	169.87	485	717 (d)	4352	1.744	-123 c
As	AsBr ₃	314.65	306	494	3540	-195.0 c	col. prisms
	AsCl ₃	181.28	265	403	2163	-335 lq	Oily liquid
	As ₂ O ₃	197.84	588		3738	1.755	-1310 c
	Au	AuCl ₃	303.33	527 (d)	3900	-118 c	col. cub. (As ₂ O ₃)
Ba	BaCl ₂	208.25	1240	1820	3856	1.736	-860.1 c
	BaO	153.34	2196	2300	5720	1.98	-558.1 c
Be	BeCl ₂	79.92	678	790	1899	1.719	-511.7 c
	BeO	25.01	2800	4170	3010	-1.719	w. delq. needles
C	CO	28.01	74	84	1.25	-110.5 g	w. hex.
	CO ₂	44.01	162	195	1.98	-393.5 g	col. gas
Ca	CaCO ₃	100.09	1612	d	2930	1.6809	-1206.9 c
	CaCl ₂	110.99	1045	1900	2150	1.52	Aragonite, col. rh.
	CaO	56.08	2850	3120	3300	1.837	w. delq. cub.

Formula	Molecular Weight M/g mol ⁻¹	Melting Point T _m /K	Boiling Point T _b /K	Density ρ/kg m ⁻³	Refractive Index n	Enthalpy of Formation ΔH _f °/kJ mol ⁻¹	Description	
Cd CdBr ₂	272.22	840	1136	5192	-314.4	c	w. eff. needles	
	CdCl ₂	183.32	841	4047	-389.1	c	w. cub.	
	CdO	128.40	1200 (d)	8150	-254.6	c	brown cub.	
Co CoCl ₂	129.84	997°	1322	2940	-326	c	blue crys. in HCl gas	
	CoO	74.93	2208	6450	-239	c	brown cub.	
	Co(OH) ₂	92.95	d	3597	-548.9	c	rose-red rh.	
Cs CsCl	168.36	919	1560	3988	1.534	-433.0	col. delq. cub.	
Cu CuO	79.54	1599		6400	-155.2	c	bl. cub. or trig.	
	CuSO ₄	223.14		3605	1.733	-769.9	gn/w. rh.	
	CuSO ₄ ·5H ₂ O	249.68		2284	1.537	-2278	c	
	Cu ₂ O	143.08	1508	6000	2.705	-166.7	c	
Fe FeS	87.91	1470	d	4740	-95.1	c	red cub.	
	Fe ₂ O ₃	159.69	1838	5240	3.042	-822.2	c	
	Fe ₃ O ₄	231.54	1810 (d)	5180	2.42	-1117	c	
H HBr	80.92	185	206	3.5	-36.2	g	col. gas	
	HCl	36.46	158	188	1.0	-92.3	g	
	HF	20.01	190	293	0.99	-268.6	g	
	HI	127.91	222	238	5.66	+25.9	g	
	HNO ₃	63.01	231	356	1503	-173.2	lq	
	H ₂ O	18.02	273	373	1000	1.333	col. liquid	
	H ₂ SO ₄	98.08	284	610	1841	-285.9	lq	
Hg HgCl	236.03	670 (s)		7150	1.973	-265°	c	
	HgCl ₂	271.50	549	575	5440	1.859	-230	c
	HgO	216.59	800 (d)	11100	2.5	-90.4	c	
K KCl	74.56	1049	1770 (s)	1984	1.490	-435.9	c	
	KHCO ₃	100.12	400 (d)	2170	1.482	-959.4	c	
	K ₂ CO ₃	138.21	1164	d	2428	1.531	-1146.1	c
	K ₂ O	94.20	620 (d)		2320	-361.5	c	
Li LiCl	42.39	887	1600	2068	1.662	-408.8	c	
Mg MgBr ₂	184.13	970		3720	-	-517.6	c	
	MgCO ₃	84.32	620	1200	2958	1.700	-1112	c
	MgCl ₂	95.22	981	1685	2320	1.675	-641.8	c
	MgF ₂	62.31	1539	2512	-	1.378	-1102	c
	MgH ₂	26.33	550 (d)		-	-	w. tetr.	
	MgI	278.12	1000 (d)		4430	-	-359	c
	MgO	40.31	3100	3900	3580	1.736	-601.8	c
	Mg(OH) ₂	58.33	620		2360	1.562	-924.7	c
	MgSO ₄	120.37	1397		2660	1.56	-1278	c
Mn MnO	70.94			5440	2.16	-385	c	
	MnO ₂	86.94	808 (d)		5026	-	-520.9	c
	MnO ₃	102.94			-	-	red delq.	
	Mn ₂ O ₃	157.87	1350 (d)		4500	-	-971.1	c
	Mn ₂ O ₇	221.87	279	328 (d)	2396	-	brown/bl. cub.	
	Mn ₃ O ₄	228.81	1978		4856	2.46	-1386	c
N NH ₃	17.03	195	240	0.77	-	-46.2	g	
	NH ₄ Cl	53.49	613 (s)		1527	1.64	-315.4	c
	NO	30.01	110	121	1.34	+90.4	g	
	NO ₂	44.01	182	185	1.98	+33.8	g	
	N ₂ O ₃	76.01	171	277 (d)	1447	+83.8	g	

Formula	Molecular Weight M/g mol ⁻¹	Melting Point T _m /K	Boiling Point T _b /K	Density ρ/kg m ⁻³	Refractive Index n	Enthalpy of Formation ΔH _f °/kJ mol ⁻¹	Description	
Na NaBr	102.90	1028	1660	3203	1.641	-359.9	c	
	NaCl	58.44	1074	1686	2165	1.544	-411.0	c
	NaF	41.99	1261	2558	1.326	-569	c	
	NaH	24.00	1100 (d)	920	1.470	-57.3	c	
	NaHCO ₃	84.00	540 (d)	2159	1.500	-947.7	c	
	NaHSO ₄	120.06	590	d	2435	-1126	c	
	NaI	149.89	924	1577	3667	1.774	-288.0	c
	NaOH	40.00	592	1660	2130	-426.7	c	
	Na ₂ CO ₃	105.99	1124	d	2532	1.535	-1131	c
	Na ₂ O	61.98	1548 (s)	2270	-	-416	c	
	Na ₂ SO ₄	142.04	-	2680	1.477	-1384	c	
Ni NiCl ₂	129.62	1274	-	3550	-	-316	c	
	NiO	74.71	2260	-	6670	2.37	-244	c
P PCl ₃	137.33	161	349	1574	1.503	-320	c	
	PCl ₃	208.24	435 (s)	4.65	-	-463.2	g	
	PH ₃	34.00	140	185	-	+5.2	g	
	P ₂ O ₃	109.95	297	447°	2135	-	-820	lq
	P ₂ O ₄	125.95	370	450°	2540	-	w. delq. rh. in vacuo	
	P ₂ O ₅	141.94	850	875	2390	-	w. delq. amor. ^a P ₄ O ₁₀	
Pb PbCl ₂	278.10	774	1220	5850	2.217	-359.2	c	
	PbCl ₄	349.00	258	378 (ex)	3180	-	yel. liquid	
	PbO	223.19	1161	-	9530	-	red amor.	
	PbO ₂	239.19	560 (d)	-	9375	2.229	-276.6	c
	PbS	239.25	1387	-	7500	3.912	-100.4	c
	Pb ₃ O ₄	685.57	770 (d)	-	9100	-	lead gray cub.	
Rb RbCl	120.92	988	1660	2800	1.494	-430.5	c	
S SO ₂	64.06	200	263	-	2.93	-296.9	g	
	SO ₃	80.06	306	318	1927°	-	-395.2	g
Sb SbBr ₃	361.48	370	550	4148	1.74	-260	c	
	SbCl ₃	228.11	347	556	3140	-	col. rh. delq.	
	SbCl ₅	299.02	276	352	2336	-	pale yel. liquid	
Si SiC	40.10	3000	-	3217	2.654	-111.7	c	
	SiCl ₄	169.90	203	331	1483	1.412	-640.2	lq
	SiH ₄	32.12	88	161	-	+34	g	
	SiO	44.09	1975	2150	-	-	col. gas	
	SiO ₂	60.08	1880	2500	1.544	-911	c	
Sn SnCl ₄	260.50	240	387	2226	-	-511.3	lq	
	SnO	134.69	1350 (d)	-	6446	-	col. fuming liquid	
	SnO ₂	150.69	1400	2100 (s)	6950	1.997	-286	c
Sr SrCl ₂	158.53	1146	1520	3052	1.536	-581	c	
	SrO	103.62	2700	3300	4700	1.870	-828	c
Ti TiCl ₄	189.71	248	409	1726	-	-590	c	
	TiO ₂	79.90	2098	-	4170	2.586	-750	lq
U UC ₂	262.05	2650	4640	11280	-	-912	c	
	UO ₂	270.03	2800	-	10960	-	bl. rh.	
W WC	195.86	3140	6300	15630	-	-1130	c	
	WO ₃	231.85	1746	-	7160	-	metallic crystals	
Zn ZnCO ₃	125.39	570 (d)	-	4398	1.818	-840	c	
	ZnCl ₂	136.28	556	1003	2910	1.687	-813	c
	ZnO	81.37	2100	-	5606	2.004	-416	c

25 Properties of Organic Compounds (at 293K)

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Enthalpies of Formation refer to the substance in the crystalline (c), liquid (lq), or gaseous (g) states at 293 K. A negative value indicates evolution of heat during formation of the compound, while a positive value indicates absorption of heat. Enthalpy changes on combustion refer to combustion at a pressure of 1 atmosphere and temperature 293 K, the final products being liquid water, and gaseous carbon dioxide and nitrogen.

Name and Formula	Molecular Weight	Melting Point T _m /K	Boiling Point T _b /K	Density ρ/kg m ⁻³	Refractive Index, n	Enthalpy of Formation ΔH _f /kJ mol ⁻¹	Heat of Combustion ΔH _c /kJ mol ⁻¹	Alternative Name
Hydrocarbons								
Methane CH ₄	16.04	91	109			-74.85 g	890.4 g	
Ethane C ₂ H ₆	30.07	90	185			-84.7 g	1560 g	
Propane C ₃ H ₈	44.11	83	231			-103.8 g	2220 g	
n-Butane n-C ₄ H ₁₀	58.13	135	273	579	1.3543	-146.2 lq	2877 g	
2-Methyl propane iso-C ₄ H ₁₀	58.13	114	261	557		-134.6 g	2869 g	
n-Pentane n-C ₅ H ₁₂	72.15	143	309	626	1.3575	-173 lq	3509 lq	
n-Hexane n-C ₆ H ₁₄	86.18	178	342	660	1.3751	-198.8 lq	4163 lq	
n-Heptane n-C ₇ H ₁₆	100.21	183	372	638	1.3878	-224.4 g	4853 lq	
n-Octane n-C ₈ H ₁₈	114.23	216	399	702	1.3974	-250 lq	5512 lq	
Ethene n-C ₂ H ₄	28.05	104	169	1.26		+52.3 g	1411 g	Ethylene
Propene C ₃ H ₆	42.08	88	226	519	1.3567	+20.4 g	2059 g	Propylene
Ethyne C ₂ H ₂	26.04	192	189	618		+226.7 g	1300 g	Acetylene
Benzene C ₆ H ₆	78.12	279	353	879	1.5011	+48.7 lq	3273 lq	
Cyclohexane C ₆ H ₁₂	84.16	280	354	779	1.4266	-156.2 lq	3924 lq	
Halogen derivatives of hydrocarbons								
Monochloromethane CH ₃ Cl	50.49	175	249	916		-81.9 g	687 g	Methyl chloride
Dichloromethane CH ₂ Cl ₂	84.93	173	313	1327	1.4242	-117 lq	447 g	Methylene dichloride
Trichloromethane CHCl ₃	119.38	210	335	1483	1.4459	-132 lq	373 lq	Chloroform
Tetrachloromethane CCl ₄	153.82	250	350	1594	1.4601	-139.5 lq	156 lq	Carbon tetrachloride
Bromomethane CH ₃ Br	94.94	180	277	1676	1.4218	-35.6 g	770 g	Methyl bromide
Iodomethane CH ₃ I	141.94	207	316	2279	1.5380	-8.4 lq	815 lq	Methyl iodide
Alcohols								
Methanol CH ₃ OH	32.04	179	338	791	1.3288	-238.7 lq	726.5 lq	
Ethanol C ₂ H ₅ OH	46.07	156	352	789	1.3611	-277.7 lq	1371 lq	
n-Propanol n-C ₃ H ₇ OH	60.11	147	371	803	1.3850	-300 lq	2017 lq	
Propane-1,2,3-triol C ₃ H ₈ O ₃	92.11	293	d	1261	1.4746	-103.9 lq	1661 lq	Glycerol
Acids								
Ethanoic acid CH ₃ COOH	60.05	290	391	1049	1.3716	-488.3 lq	876 lq	Acetic acid
Propanoic acid C ₂ H ₅ COOH	74.08	252	414	993	1.3869	-509 lq	1527 lq	Propionic acid
n-Butanoic acid n-C ₃ H ₇ COOH	88.12	269	437	958	1.3980	-538.9 lq	2193 lq	
Benzoic acid C ₆ H ₅ COOH	122.13	396	522	1266	1.504	-390 c	3227 c	
Miscellaneous								
Ethanal CH ₃ CHO	44.05	152	294	783	1.3316	-166.4 g	1192 lq	Acetaldehyde
2-Propanone CH ₃ ·CO·CH ₃	58.08	178	329	790	1.3588	-216.7 g	1821 g	Acetone
Methoxymethane CH ₃ ·O·CH ₃	46.07	135	250			-185 g	1454 g	Dimethylether
Ethoxyethane C ₂ H ₅ ·O·C ₂ H ₅	74.12	157	308	714	1.3526	-279.6 lq	2761 lq	Diethylether
Urea CO(NH ₂) ₂	60.06	408	d	1323	1.484	-333.2 c	634 c	
Glycine NH ₂ ·CH ₂ ·COOH	75.07	d		828		-528.6 c	981 c	

26 The Greek Alphabet

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A	α	Alpha	I	ι	Iota	P	ρ	Rho
B	β	Beta	K	κ	Kappa	S	σ	Sigma
Γ	γ	Gamma	Λ	λ	Lambda	T	τ	Tau
Δ	δ	Delta	M	μ	Mu	Y	υ	Upsilon
E	ε	Epsilon	N	ν	Nu	Φ	φ	Phi
Z	ζ	Zeta	Ξ	ξ	Xi	X	χ	Chi
H	η	Eta	Ο	ο	Omicron	Ψ	ψ	Psi
Θ	θ	Theta	Π	π	Pi	Ω	ω	Omega

27 Table of Isotopes

The following table lists all the stable isotopes and also includes a selection of important unstable isotopes.

Column 1 gives the atomic number, symbol and mass number of the isotope. The mass numbers of stable isotopes are printed in bold type. An asterisk with the mass number indicates an isomer (metastable excited nucleus). Column 2 gives the abundance, *a*, of the isotope in the naturally occurring element and for the unstable isotopes indicates the type of decay by the symbols: *a*, *β-*, *β+*, *-*radiation, *p* proton emission, *n* neutron emission, *k* electron capture, i.e. isomeric transition with emission of γ -rays. Column 3 gives the atomic masses in unified mass units. The masses of the nuclei can be obtained from these by subtraction of the masses of the Z electrons of mass 0.000549 u each.

Column 4 gives for unstable isotopes the maximum energy, *E*, of the emitted particles for several possible disintegrations in the order shown in column 2. Column 5 gives the corresponding half-value periods in seconds (s), minutes (min), days (d) or years (a). Column 6 gives the inner quantum number of the nucleus and the energy of gamma-rays (MeV); column 7 gives the nuclear magnetic moment (nuclear magnetons).

Element Z	Atom A	α [%] or disint.	M u	E MeV	T	I or Eγ	μ
-1e	-	stable	0.000 548 ₀				
1p	1	stable	1.007 276				
On	1	β-	1.008 665 ₄	0.78	10.8 min		-1.913 1
1 H	1	99.985	1.007 825 ₂				+2.792 6
D	2	0.015	2.014 102 ₂				+0.857 3
T	3	β-	3.016 049	0.018	12.3 s		+2.978 5
2 He	3	1.4×10 ⁻⁴	3.016 030				-2.127 4
	4	~100	4.002 604				0 0
	5	<i>n</i>	5.012 3 ₀				
	6	β-	6.018 9	3.5	~6×10 ⁻²⁰ s	0	0
3 Li	5	p	5.012 5		0.82 s		
	6	7.42	6.015 12 ₆				
	7	92.58	7.016 00 ₃				
	8	β-	8.022 48 ₈				+0.821 9
	9	β-+n	9.02 ₇	~1 ² β~8	0.84 s 0.17 s		+3.256 1.65

Table of Isotopes

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Element Z	A	$\alpha[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
4 Be	7	K	7-016 93 ₁		53 d	0-48	
	8	2α	8-005 30 ₀	0-05	$\sim 3 \times 10^{-14}$ s	0	0
	9	100	9-012 18 ₀			$\frac{1}{2}$	-1.1774
	10	β^-	10-013 54 ₀	0-56	2.7×10^6 a	0	0
5 B	11	β^-	11-021 06 ₀	11.5; 9.3	14 s	2.8	
	8	$\beta^+ + 2\alpha$	8-024 61 ₂	$\beta/14$	0.8 s		
	9		9-013 33 ₀				
	10	19.6	10-012 93 ₀			3	+1.801
6 C	11	80.4	11-009 305			$\frac{1}{2}$	+2.689
	12	$\beta^-(+a)$	12-014 35 ₀	13.4	0.02 s	1	.
	13	β^-	13-017 78		0.04 s		
	10	β^+	10-016 8 ₁	2.1	19 s	0	0
7 N	11	β^+	11-011 43	0.96	20.5 min	$\frac{1}{2}$	
	12	98.89	12 (Stand.)			0	0
	13	1-11	13-003 35 ₀			$\frac{1}{2}$	+0.7022
	14	β^-	14-003 242	0.158	5570 a	0	0
8 O	15	β^-	15-010 60 ₀	9.8; 4.5	2.3 s	5.3	
	12	β^+	($\beta^+ + 3a$) 12-018 7	16.6; 12.2	0.012 s		
	13	β^+	13-005 73 ₀	1.2	10.1 min	$\frac{1}{2}$	
	14	99.63 ₀	14-003 074			1	+0.4037
9 F	15	0.36 ₀	15-000 10 ₀			$\frac{1}{2}$	-0.2830
	16	β^-	16-006 0 ₀	10.4; 4.3	7.4 s	2	
	17	$\beta^- + n$	17-008 4 ₀	3.7 (0.9)	4.1 s		
	14	β^+	14-008 597	1.8	72 s	2.3	
10 Ne	15	β^+	15-003 07 ₂	1.68	124 s	$\frac{1}{2};$ noy	
	16	99.76	15-994 915 ₁			0	0
	17	0-037 4	16-999 13 ₀			$\frac{1}{2}$	-1.893
	18	0-204	17-999 160			0	0
11 Na	19	β^-	19-003 58	4.6; 3.2	29.4 s		
	17	β^+	17-002 10	1.75	66 s		
	18	$\beta^-(K)$	18-000 95	0.65	110 min		
	19	100	18-998 40			$\frac{1}{2}$	+2.628
21	20	β^-	19-999 99	5.4	11 s	2; 1.63	
	18	β^+	18-005 7 ₂	3.4	1.3 s		
	19	β^+	19-001 89	2.2	18 s		
	20	90.92	19-992 440			0	0
22	21	0.257	20-993 84 ₀			$\frac{1}{2}$	-0.662
	22	8.82	21-991 384			0	0
	23	β^-	22-994 47	4.4; 3.9	38 s	0.44	
	24	β^-	23-993 6	2.0; 1.1	3.4 min	0.47; 0.88	
25	20	$\beta^+ + \alpha$	20-008 ₉	$3.5 < E_\alpha <$ $7.3; E_\alpha > 2$	0.3 s		
	21	β^+	20-997 6 ₄	2.5	23 s		
	22	$\beta^+(K)$	21-994 44	0.54	2.6 a	3; 1.28	+1.746
	23	100	22-989 77 ₃	1.4	15 h	$\frac{1}{2}$	+2.2165
26	24	β^-	23-990 97	~ 6	0.02 s	0.47	+1.688
	1. t., β^-						
	25	β^-	24-989 ₉	3.8; 2.8	60 s	0.4...1.6	

Table of Isotopes (Cont.)

89

Element Z	A	$\alpha[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
12 Mg	23	β^+	22-994 14	3.1; 2.6	12 s	0.44	
	24		23-985 04 ₅			0	0
	25	10.1	24-985 84 ₀			$\frac{1}{2}$	-0.855
	26	11.2	25-982 59 ₁			0	0
	27	β^-	26-984 35	1.8; 1.6	9.5 min	0.83; 1.0	
	28	β^-	27-983 8 ₈	0.4	21.3 h	0.03...1.3	0
	13 Al	$\beta^+ + \alpha$	24-000	$\beta: 8.5; \alpha: 2$	2.1 s	1.4...7.1	
	24	β^+	24-990 4 ₁	3.2	7.2 s	1.6	
14 Si	25	β^+	25-986 90	1.2	7×10^3 a	1.1; 1.8	
	26*	β^+		3.2	6.5 s		+3.639
	27	100	26-981 53 ₃			$\frac{1}{2}$	
	28	β^-	27-981 91	2.9	2.3 min	1.8	
	29	β^-	28-980 44	2.5; 1.5	6.6 min	1.3; 2.4	
	30	3.09	29-973 76	3.8	4 s	0	
	31	β^-	30-975 35	1.5	157 min		
	32	β^-	31-974 0	~ 0.1	~ 700 s	0	0
15 P	28	β^+	27-992	10.6	0.28 s	1.8...7.6	
	29	β^+	28-981 8 ₂	3.9	4.3 s		
	30	β^+	29-978 3 ₂	3.2	2.5 min		
	31	100	30-973 76 ₀	1.7	14.5 d	$\frac{1}{2}$; noy	+1.131
	32	β^-	31-973 90 ₀	0.25	25 d		-0.252
	33	β^-	32-971 73	0.25			
	34	β^-	33-973 ₃	5.1; 3.2	12.4 s	2.1	
	35	β^+	30-979 6 ₀	4.4	2.6 s		
16 S	31	95.0	31-972 07 ₄			0	0
	32	0.76	32-971 46			$\frac{1}{2}$	+0.643
	33	4.22	33-967 86			0	0
	34	β^-	34-969 03	0.167	87 d	$\frac{1}{2}$	(+) 1.0
	35	0.014	35-967 0 ₀			0	0
	36	β^-	36-971 ₀	4.7; 1.6	5.0 min	2.7	
	37	β^-	37-971 ₂	3.0; 1.1	2.9 h	1.9	
	38	β^-	37-971 ₀	4.5	2.8 s		
17 Cl	32	$\beta^+ + \alpha$	31-986	9.5; 8.2	0.3 s	4.3; 4.8	
	33	β^+	32-977 ₄	4.5	1.5 s		
	34	β^+	33-973 7 ₆	4.5			
	35	75.5	34-968 85			$\frac{1}{2}, t.; 0.14$	
	36	$\beta^-(K)$	35-968 3 ₁	0.71	3×10^3 a	2	+1.284
	37	24.5	36-965 90			$\frac{1}{2}$	+0.684
	38	β^-	37-968 0 ₀	4.8; 2.8; 1.1	37.3 min	1.6; 2.2	
	39	β^-	38-968 0	3.5; 2.2; 1.9	56 min	0.2...1.5	
18 Ar	40	β^-	39-970	7.5; 3.2	1.4 min	1.5...6.0	
	35	β^+	34-975 3	4.96	2 s	1.2; 1.7	
	36	0.337	35-967 55			0	0
	37	K	36-966 77			34 d	1.0
25	38	0.063	37-965 72			0	0

Table of Isotopes (Cont.)

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Element Z	A	$a[\%]$ or disint.	M u	E MeV	T	I or E _y	μ
19 K	39	β^-	38.964 3 ₂	0.56	265 a	0	0
	40	99.60	39.962 38 ₄	2.5; 1.2	110 min	1.3	
	41	β^-	40.964 5 ₀	5	1.2 s		
	37	β^+	36.973 4	2.7	7.7 min	2.2	
	38	β^+	37.969 1	5.1	0.95 s		
	*38	β^+					
	39	93.10	38.963 71				
20 Ca	40	0.011 8 β^-	39.964 01	1.32	1.3 $\times 10^9$ a	$\frac{1}{2}$	+0.391
						4	-1.297
						1.46	
	41	6.88	40.961 83				+0.215
	42	β^-	41.962 4	3.6; 2.2	12.5 h	2; 1.5	-1.14
	39	β^+	38.970 7	5.5	0.9 s	0	0
	40	96.97	39.962 59			0	0
21 Sc	42	0.64	41.958 63			0	0
	43	0.14	42.958 78			$\frac{1}{2}$	-1.315
	44	2.1	43.955 49			0	0
	45	β^-	44.956 19	0.26	165 d		
	46	0.003	45.953 6 ₀			0	0
	47	β^-	46.954 5	1.94; 0.66	4.7 d	1.3	
	48	0.18	47.952 3 ₆			0	0
22 Ti	49	β^-	48.955 6 ₆	2.0; 0.9	8.8 min	3.1; 4.0	
	45	100	44.955 92			$\frac{1}{2}$	+4.749
	46	β^-	45.955 1 ₇	0.36	84 d		
	*46	i. t.			20 s	0.14	
	47	β^-	46.952 4 ₆	0.6; 0.44	3.4 d	0.16	
	48	β^-	47.952 2 ₃	0.65	44 h	1.0; 1.3	
	46	7.93	45.952 63			0	0
23 V	47	7.28	46.951 7 ₆			$\frac{1}{2}$	-0.787
	48	73.94	47.947 95			0	0
	49	5.51	48.947 87			$\frac{1}{2}$	-1.102
	50	5.34	49.944 79			0	0
	51	β^-	50.946 6	2.1; 1.5	5.8 min	0.3; 0.6; 0.9	
	48	β^+, K	47.952 2 ₆	0.70	16 d	1.0; 1.3	
	50	0.24; K	49.947 17		4 $\times 10^{14}$ a	6	+3.341
24 Cr	51	99.76	50.943 98			$\frac{1}{2}$	+5.14
	52	β^-	51.944 8 ₀	2.6	3.77 min	1.4	
	50	4.31	49.946 05			0	0
	51	K	50.944 79		28 d	$\frac{1}{2}; 0.32$	
	52	83.76	51.940 51			0	0
	53	9.55	52.940 65			$\frac{1}{2}$	-0.474
	54	2.38	53.938 88			0	0
25 Mn	55	β^-	54.941 ₁	2.8	3.5 min		
	54	K	53.940 3 ₆		280 d	3; 0.84	3.3
	55	100	54.938 05			$\frac{1}{2}$	+3.462
	56	β^-	55.938 9 ₁	2.9; 1.0	2.6 h	3; 0.8...2.1	+3.240
26 Fe	54	5.82	53.939 6 ₂			0	0
	55	K	54.938 30		2.7 a	0.21	
	56	91.66	55.934 9 ₃			0	0
	57	2.19	56.935 3 ₉			$\frac{1}{2}$	+0.09

Table of Isotopes (Cont.)

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Element Z	A	$a[\%]$ or disint.	M u	E MeV	T	I or E _y	μ
27 Co	58	0.33	57.933 2 ₇			0	0
	59	β^-	58.934 8 ₇	0.46; 0.27	45 d	1.1; 1.3	
	57	K	56.936 29		270 d	$\frac{1}{2}$	4.6
	58	K(β^+)	57.935 7 ₉	0.47	71 d	2; 0.01...1.2	4.1
	59	100	58.933 19			$\frac{1}{2}$	+4.64
	60	β^-	59.933 8 ₁	0.314	5.29 a	5; 1.17; 1.33	+3.8
	*60	i. t. -		1.5	10.5 min	0.06	
28 Ni	58	67.9	57.935 3 ₆		$\sim 10^4$ a	0	0
	59	K	58.934 3 ₆			0	0
	60	26.2	59.930 7 ₉			$\frac{1}{2}$	0.3
	61	1.2	60.931 0 ₉			0	0
	62	3.7	61.928 3 ₃			0	0
	63	β^-	62.926,	0.067	120 a	0	0
	64	1.1	63.927 9 ₆	2.1; 1.0; 0.6	2.6 h	0.4; 1.1; 1.5	+2.221
29 Cu	63	69.1	62.929 5 ₉	β^- ; 0.57	12.8 h	1.34	0.22
	64	β^-, β^+, K	63.929 7 ₆	β^+ ; 0.66			
	65	30.9	64.927 7 ₉			$\frac{1}{2}$	+2.379
	66	β^-	65.928 8 ₇	2.6; 1.6	5.1 min	1.0	
	64	48.89	63.929 15			0	0
	65	K, β^+	64.929 2 ₃	0.33	245 d	1.1	
	66	27.81	65.926 0 ₉			0	0
30 Zn	67	4.11	66.927 1 ₉			$\frac{1}{2}$	+0.874
	68	18.57	67.924 8 ₇			0	0
	69	β^-	68.926 7	0.9	55 min	0	
	70	i. t.			14 h	0.44	
	70	0.62	69.925 3 ₃			0	0
	71	β^-	70.928 0	2.3	2.2 min		
	31 Ga	69	60.4	68.925 7		$\frac{1}{2}$	+2.011
32 Ge	70	β^-	69.926 0 ₉	1.6	21 min	0	
	71	39.6	70.924 8			$\frac{1}{2}$	+2.555
	72	β^-	71.926 0	3.2...0.6	14 h	3; 0.5...2.8	-0.132
	71	20.5	69.924 2 ₈			0	0
	71	K	70.925 1			$\frac{1}{2}$	0
	72	27.4	71.921 7			0	0
	73	7.8	72.923 ₄			$\frac{1}{2}$	-0.877
33 As	74	36.5	73.921 ₂			0	0
	75	β^-	74.922 ₀	1.2; 0.9	84 min	0.26	
	73	i. t.			46 s	0.14	
	76	7.8	75.921 ₄			0	
	77	β^-	76.923 ₆	2.2; 1.4; 0.7	12 h	0.22 u.a.	0
	75	β^-	74.921 ₂			$\frac{1}{2}$	
	74	K, β^-, β^+	73.923 ₉	β^- ; 1.4; 0.7	18 d	0.6 u.a.	
34 Se	75	100	74.921 ₁	β^+ ; 1.5; 0.9			
	76	β^-	75.922 4	3.0; 2.4	26.5 h	2; 0.6; 1.2	+1.435
	77	β^-	76.920 ₇	0.7	39 h	0.09...0.5	-0.90

Table of Isotopes (Cont.)

Element Z	A	$a[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
34 Se	74	0.9	73.922 ₄			0	0
	75	K	74.922 ₅		120 d	0; 0.02...0.4	+1.1
	76	9.0	75.919 ₂			0	0
	77	7.6	76.919 ₁			½	0.533
	*77	i. t.			17.4 s	0.16	
	78	23.5	77.917 ₄			0	0
	80	49.8	79.916 ₅	1.4	18 min	0	0
	81	β^-			60 min	0.10	
	*81	i. t.				0	0
	82	9.2	81.916 ₇	1.6; 1.0; 0.4	25 min	0.2...2.3	
35 Br	83	β^-	82.918 ₉	3.4; 1.5	70 s	0.4...2.0	
	79	50.54	78.918 ₄	2.0; 1.4 (0.9)	18 min	1; 0.62	+2.099
	80	$\beta^-(K, \beta^+)$			4.7 h	5; 0.05	
	*80	i. t.					
	81	49.46	80.916 ₃				
	82	β^-	81.916 ₈	0.44	36 h	5; 0.5...1.5	+2.263
	87	$\beta^-, \beta^- + n$	86.922	β^- ; 8.0; 2.6	56 s	5.4; 3	(+) 1.626
	78	0.35	77.920 ₃			0	
	79	$K(\beta^+)$	78.920 ₁	(0.6; 0.3)	34.5 h	0.04...0.8	
	80	2.27	79.916 ₃			0	
36 Kr	82	11.56	81.913 ₄			0	
	83	11.55	82.914 ₁			½	-0.97
	84	56.9	83.911 ₅			0	0
	85	β^-	84.912 ₄	0.67	10 a	½; 0.5	-1.0
	*85	$\beta^-, i. t.$		0.8	4.5 h	0.15	
	86	17.37	85.910 ₆			0	
	87	β^-	86.913 ₄	3.8; 1.3	78 min	0.4; 0.9; 2.6	
	85	72.15	84.911 ₇				
	86	β^-	85.911 ₂	1.8; 0.7 1.0 min	18.7 d	2; 1.1	+1.348
	*86	i. t.		0.6		-1.67	
37 Rb	87	27.85 β^-	86.909 ₂	0.27	4.7×10^{10} a	½	+2.741
	88	β^-	87.911 ₂	5.2; 3.6; 2.5	18 min	2; 0.9; 1.8	
	84	0.56	83.913 ₃			0	
	86	9.9	85.909 ₃			0	
	87	7.0 (β^-)	86.908 ₉			½	-1.09
	*87	i. t.			2.9 h	0.39	
	88	82.6	87.905 ₆			0	
	89	β^-	88.907 ₁	1.46	51 d		
	90	$\beta^- \rightarrow ^{20}Y$	89.907 ₃	0.54	28 a	no γ	
	89	100	88.905 ₄			½	-0.137
38 Sr	90	β^-	89.906 ₇	2.26	64 h	2; no γ	-1.6
	91	β^-	90.906 ₉	1.5; 0.3	58 d	1.2	
	*91	i. t.			50 min	0.55	
	90	51.5	89.904 ₃			0	
	91	11.2	90.905 ₃			½	-1.30
	92	17.1	91.904 ₆			0	
	94	17.4	93.906 ₅			0	
	95	β^-	94.908 ₈	0.40; 0.36	65 d	0.73; 0.76	

Table of Isotopes (Cont.)

Element Z	A	$a[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
41 Nb	96	2.8 (β^-)	95.908			0	0
	97	β^-	96.911	1.9; 0.4	17.0 h	0.5 ... 2.6	6.14
	93	100	92.906 ₀			0.042	
	*94	i. t.				0.23	
	95	β^-	94.907	(0.9); 0.16	35 d	0.75; 0.77	
	42 Mo	15.8	91.906 ₃		90 h	0	0
	94	9.0	93.904 ₇			0	0
	95	15.7	94.906			0	-0.910
	96	16.5	95.905			0	-0.929
	97	9.5	96.906			0	
43 Tc	98	23.5	97.906			0	
	99	β^-	98.908	1.2; 0.5	67 h	0.04 ... 0.78	
	100	9.6	99.908			0	
	101	β^-	100.908 ₉	2.2 ... 0.6	14.6 min	0.08 ... 2.1	
	96	K	95.908		4.35 d	1.12	
	97	K			2.6 $\times 10^6$ a		
	99	β^-	98.906	0.3	2.1 $\times 10^5$ a	0.14	+5.657
	101	β^-	100.905 ₉	1.3 (1.1)	6 h	0.1 ... 0.9	
	44 Ru	96	5.5	95.908	14 min	0	
	97	K			2.9 d	0.4; 0.22; 0.33	
45 Rh	98	1.9	97.906			0	
	99	12.7	98.906			0	-0.6
	100	12.6	99.903 ₀			0	
	101	17.1	100.904 ₁			0	-0.7
	102	31.6	101.903 ₇			0	
	103	β^-	102.905 ₆	0.2; 0.1	40 d	0.50; 0.61	
	104	18.6	103.905 ₅			0	
	105	β^-	104.907 ₃	1.15	4.45 h	0.26 ... 0.96	
	106	β^-	105.907 ₀	0.04	1.0 a		-0.088
	104	β^-	103.906 ₂	2.4; 1.9; 0.7	42 s	0.56; 1.2	
46 Pd	*104	i. t. (β^-)			4.4 min	0.05; 0.08	
	105	β^-	104.905 ₃	0.56; 0.25	35 h	0.32 u. a.	
	*105	i. t.			30 s	0.13	
	106	β^-	105.907 ₀	3.5; 3.1; 2.4	30 s	0.5 ... 2.7	
	102	1.0	101.904 ₉			0	
	103	K	102.905 ₄			0	
	104	11.0	103.903 ₆			0	
	105	22.2	104.904 ₆			0	
	106	27.3	105.903 ₂			0	
	108	2.67	107.903 ₉			0	
47 Ag	109	β^-	108.905 ₉	1.0	13.6 h	0.18	
	*109	i. t.			4.8 min	0	
	110	11.8	109.904 ₅			0	
	111	β^-	110.907 ₆	2.1	22 min	0.4 ... 1.4	
	105	K	104.906 ₈		45 d	0.06 ... 0.65	
	107	51.4	106.905 ₀			0	-0.113
	*107	i. t.			44 s	0.094	

Table of Isotopes (Cont.)

Z	Element A	$a[\%]$ or disint.	M_u	E_MeV	T	I or E γ	μ
48 Cd	108	$\beta^-(K, \beta^+)$	107-905 ₉	$\beta^-: 1.77; \beta^+: 0.8$	2.4 min	0.4; 0.6	
	109	48.6	108-904 ₇				
	*109	i. t.			39 s	0.088	
	110	β^-	109-906 ₁	2.9; 2.2 0.53; 0.09	24.5 s 253 d	0.66 6; 0.1 ... 1.5	
	*110	$\beta^-(i.t.)$				$\frac{1}{2}; 0.34$	0.14
	111	β^-	110-905 ₂	1.05; 0.7	7.5 d	0	0
	106	1.22	105-906 ₀				
	108	0.88	107-904 ₀				
	109	K	108-904 ₉		470 d	$\frac{1}{2}; ^{109}\text{Ag}^*$	-0.83
	110	12.39	109-903 ₀			0	0
	111	12.75	110-904 ₂				
	112	24.07	111-902 ₈			0	0
	113	12.26($\beta^-?$)	112-904 ₆		$\geq 3 \times 10^{15}$ a	$\frac{1}{2}$	-0.619
	114	28.86	113-903 ₆			0	0
	115	β^-	114-905 ₆	1.1; 0.6 1.6	2.3 d 43 d	0.2 ... 0.5 0.5 ... 1.3	
49 In	116	7.58	115-905 ₀			0	0
	117	β^-	116-907 ₄	1.8	50 min	0.42	
	*117	β^-		1.0	3 h	0.3 ... 2.2	
	113	4.3	112-904 ₃			$\frac{1}{2}$	+5.50
	*113	i. t.				$\frac{1}{2}; 0.39$	
	114	$\beta^-(K, \beta^+)$	113-905 ₁	2.0	72 s	1.3	
	*114	i. t. (K)				5; 0.19; 0.55;	+4.7
	115	95.7 β^-	114-904 ₁	0.6	6×10^{14} a	$\frac{1}{2}$	+5.51
	116	β^-	115-905 ₆	3.3	14 s	0.72	
	*116	β^-		1.0; 0.9; 0.6	54 min	5; 0.1 ... 2.1	+4.4
50 Sn	112	0.96	111-905 ₀			0	0
	113	K	112-905 ₀		119 d	0.26; $^{113}\text{In}^*$	
	114	0.66	113-903 ₀			0	0
	115	0.35	114-903 ₉			$\frac{1}{2}$	-0.913
	116	14.30	115-902 ₁			0	0
	117	7.61	116-903 ₁			$\frac{1}{2}$	-0.995
	*117	i. t.			14 d	0.16	
	118	24.03	117-901 ₀			0	0
	119	8.58	118-903 ₄			$\frac{1}{2}$	-1.041
	*119	i. t.			245 d	$\frac{1}{2}; 0.02; 0.07$	+0.8
51 Sb	120	32.85	119-902 ₁	0.38	27 h	0	0
	121	β^-	120-904 ₃	0.42	>5 a		
	*121	β^-					
	122	4.72	121-903 ₄			0	0
	123	β^-	122-905 ₇	1.4; 0.4 1.3	125 d 40 min	1.1 0.15	
	*123	β^-					
	124	5.94	123-905 ₂	2.4; 0.4		0.2 ... 1.9	
	125	β^-	124-907 ₀	2.0; 0.5	10 min	0.3 ... 1.9	
	*125	β^-					
	121	57.25	120-903 ₀	2.0; 1.4; 0.7	2.8 d	$\frac{1}{2}; 0.56 ... 1.3$	+3.34
	*122	$\beta^-(K, \beta^+)$	121-905 ₁		3.5 min	0.07; 0.06	-1.9

Table of Isotopes (Cont.)

Z	Element A	$a[\%]$ or disint.	M_u	E_MeV	T	I or E γ	μ
52 Te	123	42.75	122-904 ₂				
	124	β^-	123-905 ₉	2.3-3.0	60 d	$\frac{1}{2}; 0.6 ... 2.1$	+2.53
	*124	i. t., β^-		3.2	1.3 min	0.01	
	*124	i. t., β^-		2.5	21 min	0.02	
	125	β^-	124-905 ₂	0.6 ... 0.1	2 a	0.04 ... 0.6	
	120	0.09	119-905			0	0
	121	K				17 d	0.57
	122	2.48	121-903 ₀				0
	123	0.87 ($K^?$)	122-904 ₂				0
	*123	i. t.				$>5 \times 10^{13}$ a	-0.732
	124	4.16	123-902 ₀			104 d	0.09; 0.16
	125	6.99	124-904 ₄				-0.882
	*125	i. t.				58 d	0.04; 0.11
	126	18.7	125-903 2			9.3 h	0.06 ... 0.4
	127	β^-	126-905 1	0.7		105 d	0.09 (0.66)
53 I	128	31.8	127-904 ₇			73 min	0.03 ... 1.1
	129	β^-	128-906 5 _a	1.5		33 d	0.11
	130	34.5	129-906 ₇				0
	131	β^-	130-908 5 _a	2.1; 1.7; 1.4		25 min	0.1 ... 1.1
	*131	β^- , i. t.		2.5 ... 0.4		1.2 d	0.1 ... 1.1; 0.18
	125	K	124-904 ₆			60 d	$\frac{1}{2}; 0.035$
	127	100	126-904 3 _s				3
	128	β^-, K	127-905 8 _s	2.1; 1.1			2.79
	129	β^-	128-904 9 _s	0.15			2.60
	131	β^-	130-906 1 _s	0.61; 0.33;		8.1 d	0.08 ... 0.7;
54 Xe	135	β^-		0.25			0.36
	124	0.096	123-906 ₁	1.4; 1.0; 0.5			
	126	0.09	125-904 2				0
	128	1.92	127-903 5 _s				0
	129	26.44	128-904 7 _s				-0.773
	130	4.08	129-903 5 _s				0
	131	21.18	130-905 0 _s				0
	132	26.89	131-904 1 _s				+0.687
	133	β^-	132-905 ₆	0.35		5.3 d	0.081
	*133	i. t.				2.3 d	0.23
55 Cs	134	10.44	133-905 4 _s				0
	135	β^-	134-909 ₀	0.9; 0.55		9.1 h	0.25; 0.6
	*135	i. t.				15 min	0.53
	136	8.87	135-907 2 _s				0
	137	β^-		3.5		3.9 min	
	131	K	130-905 4 _s			10 d	
	133	100	132-905 ₁				+3.5
51 Sb	134	β^-	133-906 ₅	1.4 ... 0.6 ...		2.2 a	+2.564
	*134	i. t. (β^-)		0.09		3.1 h	+2.97

Table of Isotopes (Cont.)

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Element Z	A	$\alpha[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
56 Ba	135	β^-	134.905 ₈	0.21	2×10^6 a	$\frac{1}{2}$	+2.713
	137	$\beta^- \rightarrow ^{137}\text{Ba}^*$	136.906 ₈	1.2; 0.51	28 a	$\frac{1}{2}$	+2.822
	130	0.101	129.906 _{2s}			0	0
	131	K			12 d	0.06 ... 1.7	
	132	0.097	131.905			0	0
	133	K	132.905 ₆		7.5 a	0.05 ... 0.38	
	*133	i.t.			39 h	0.01 ... 0.28	
	134	2.42	133.904 ₃			0	0
	135	6.59	134.905 ₆			$\frac{1}{2}$	+0.832
	136	7.81	135.904 ₄			0	0
57 La	137	11.32	136.905 ₆			$\frac{1}{2}$	+0.931
	*137	i.t.			2.6 min	0.662	
	138	71.66	137.905 ₀			0	0
	139	β^-	138.908 ₆	2.4; 2.2; 0.8	85 min	0.16; 1.4	
	140	$\beta^- \rightarrow ^{140}\text{La}$	139.910 _s	1.0 ... 0.5	12.8 d	0.03 ... 0.54	
	138	0.089 K, β^-	137.906 ₀	0.21	1.1×10^{11} a	5; 1.4; 0.81	+3.68
	139	99.91	138.906 ₁			$\frac{1}{2}$	+2.761
	140	β^-	139.909 ₃	2.2 ... 0.4	40.2 h	3; 0.07 ... 2.9	
	136	0.19	135.907			0	0
	138	0.25	137.905 ₇			0	0
58 Ce	139	K	138.906 ₄			140 d	$\frac{1}{2}; 0.166$
	140	88.5	139.905 ₃			0	0.8
	141	β^-	140.908 ₀	0.58; 0.44	33 d	$\frac{1}{2}; 0.15$	0.9
	142	11.1 α	141.909 ₀	1.5	5×10^{15} a	0	0
	143	β^-	142.921 ₂	1.4 ... 0.2	33 h	0.06 ... 1.1	
	144	$\beta^- \rightarrow ^{144}\text{Pr}$	143.913 ₄	0.32; 0.24	284 d	0.03 ... 0.13	
				0.18			
	141	100	140.907 4			$\frac{1}{2}$	+3.9
	142	β^-	141.909 8	2.15; 0.6	19 h	2; 1.57	
	143	β^-	142.910 6	0.93	13.6 h		
60 Nd	144	β^-	143.913 1	3.0; 2.3; 0.8	17.3 min	0.7; 1.5; 2.2	
	142	27.1	141.907 5			0	0
	143	12.2	142.909 6			$\frac{1}{2}$	-1.1
	144	23.8 α	143.909 9	1.8	5×10^{15} a	0	0
	145	8.30	144.912 ₂			$\frac{1}{2}$	-0.7
	146	17.2	145.912 ₇			0	0
	147	β^-	146.915 8	0.81 ... 0.2	11.9 d	$\frac{1}{2}$	0.6
	148	5.73	147.916 ₅			0	0
	149	β^-	148.919 ₈	1.5; 1.1; 0.95	2 h	0.65 ... 0.03	
	150	5.62	149.920 ₇			0	0
61 Pm	145	K	144.912 ₃		18 a	0.067; 0.073	
	147	β^-	146.914 9	0.22	2.6 a	$\frac{1}{2}; 0.12$	+2.7
62 Sm	144	3.1	143.911 ₇			0	0
	147	15.0 α	146.914 6	2.1	1.3×10^{11} a	$\frac{1}{2}$	-0.08
	148	11.2	147.914 ₆			0	0
	149	13.8	148.916 ₉			$\frac{1}{2}$	-0.6
	150	7.4	149.917 ₀			0	0
	151	β^-	150.919 ₇	0.08	~ 93 a	0.02	
	152	26.7	151.919 ₅			0	0
	153	β^-	152.921 ₇	0.80; 0.7; 0.6	47 h	$\frac{1}{2}; 0.07 ... 0.6$	

Table of Isotopes (Cont.)

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Element Z	A	$\alpha[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
63 Eu	154	22.7	153.922 ₀			$\frac{1}{2}$	0
	155	β^-	154.924 ₇			1.6	0.10; 0.14; 0.25
	151	47.8	150.919 ₆				3.6
	152	K, β^-, β^+	151.921 _s	$\beta^-; 1.5 ... 0.2$	12.5 a	$3; 0.1 ... 1.4$	2.0
	*152	β^-, K, β^+		$\beta^+: 1.9; 1.6$	9.3 h	0.1 ... 1.4	
	153	52.2	152.920 ₀				1.6
	154	β^-	153.922 _s	1.9 ... 0.15	16 a	$3; 0.1 ... 1.6$	2.1
	152	0.20 a	151.919 _s		10^{15} a	0	0
	153	K	152.921 _s		200 d	0.08 ... 0.1	
	154	2.15	153.920 ₇			0	0
64 Gd	155	14.7	154.922 ₆				
	156	20.5	155.922 ₁			0	-0.3
	157	15.7	156.923 ₉			$\frac{1}{2}$	-0.4
	158	24.9	157.924 ₁			0	0
	159	β^-	158.926 ₀	0.94; 0.88; 0.6	18 h	$\frac{1}{2}; 0.06 ... 0.36$	
	160	21.9	159.927 ₁			0	0
	161	β^-	160.929 ₃	1.6; 1.5	3.7 min	0.06 ... 0.53	
	159	100	158.925 ₀				~ 1.5
	160	β^-	159.926 ₈	1.7 ... 0.3	73 d	$3; 0.06 ... 1.5$	
	165	0.05	155.923 ₈			0	0
65 Tb	158	0.09	157.924 ₀			0	0
	160	2.29	159.924 ₈			0	0
	161	18.9	160.926 ₆			$\frac{1}{2}$	0.4
	162	25.5	161.926 ₃			0	0
	163	25.0	162.928 ₄			$\frac{1}{2}$	0.5
	164	28.2	163.928 ₈			0	0
	165	β^-	164.931 ₇	1.3; 1.2; 0.3	140 min	$\frac{1}{2}; 0.04 ... 1.1$	
	*165	i.t. (β^-)		0.9	1.2 min	0.11	
	165	100	164.930 ₃				
	166	β^-	165.932 ₄	1.84 ... 0.23	27 h	0.08 ... 1.6	3.3
68 Er	162	0.14	161.938 ₈			0	
	164	1.56	163.929 ₃			0	0
	166	33.4	165.930 ₄			0	0
	167	22.9	166.932 ₁			$\frac{1}{2}$	0.5
	*167	i.t.				2.5 s	0.21
	168	27.1	167.932 ₆			0	0
	169	β^-	168.934 ₇	0.34; 0.33	9 d	$\frac{1}{2}; 0.008$	
	170	14.9	169.935 ₅			0	0
	171	β^-	170.938 ₂	1.5; 1.1	7.5 h	$\frac{1}{2}; 0.005 ... 0.9$	
	69 Tm	169	168.934				
70 Yb	170	$\beta^- (K)$	169.935 ₉	0.97; 0.88	129 d	$\frac{1}{2}; 0.08$	-0.2
	168	0.14	167.933 ₈			0	0
	169	K				32 d	0.008 ... 0.31
	170	3.1	169.934 ₉			0	0
	171	14.3	170.936 ₅			$\frac{1}{2}$	-0.5
	172	21.8	171.936 ₆			0	0
	173	16.1	172.939 ₀			$\frac{1}{2}$	-0.7
	174	31.8	173.939 ₀			0	0

Table of Isotopes (Cont.)

Z	Element A	$\alpha[\%]$ or disint.	M_u	E MeV	T	I or E_γ	μ
71 Lu	175	β^-	174.941 ₄	0.47; 0.35; 0.07	4.2 d	0.11 ... 0.4	
	176	12.7	175.942 ₇			0	0
	177	β^-	176.945 ₅	1.4 ... 0.2	2 h	0.12 ... 1.2	0
	175	97.4	174.940 ₉				
	176	2.6 β^-	175.942 ₇	0.4	2×10^{10} a	7; 0.09; 0.2; 0.3	+2.0
	*176	β^-		1.2; 1.1	4 h	1; 0.09	+2.8
	177	β^-	176.944 ₀	0.50 ... 0.18	6.8 d	4; 0.07 ... 0.32	
	174	0.18	173.940 ₃			0	0
	175	K			70 d	0.09 ... 0.43	
	176	5.2	175.941 ₄			0	0
72 Hf	177	18.5	176.943 ₅				
	178	27.1	177.943 ₉			0	0.6
	179	13.8	178.946 ₀				-0.5
	180	35.2	179.946 ₈			0	
	181	β^-	180.949 ₁	1.0; 0.41	45 d	0.004 ... 0.48	
						... 0.70	
	73 Ta	180	0.012	179.947 5			
	181	99.99	180.948 0				
74 W	182	β^-	181.950 1	0.51	115 d	0.03 ... 1.5	2.34
	*182	i.t.			16 min	0.15 ... 0.36	
	180	0.14 α	179.947 0		3×10^{14} a	0	
	181	K	180.948 2	3	145 d	0.14	
	182	26.4	181.942 3			0	
	183	14.4	182.950 3				
	184	30.6	183.951 0			0	
	185	β^-	184.953 ₅	0.43	74 d	0.125	
	*185	i.t.			1.7 min	0.07 ... 0.17	
	186	28.4	185.954 3			0	
75 Re	187	β^-	186.957 4	1.3; 0.6; 0.3	24 h	0.07 ... 0.87	
	185	37.1	184.953 ₀				
	186	β^-, K	185.955 ₁	1.07; 0.93	90 h	0.14 ... 0.77	+3.14
	187	62.9 β^-	186.956 0	0.04	10^{11} a		+3.18
	188	β^-	187.958 ₂	2.1; 2.0	17 h	0.16 ... 2.0	
76 Os	184	0.02	183.952 ₆			0	
	186	1.6	185.954 ₀			0	
	187	1.6	186.956 0				
	188	13.3	187.956 ₀			0	+0.07
	189	16.1	188.958 ₃			0	
	190	26.4	189.958 ₆				+0.651
	191	β^-	190.961 ₂	0.14	15 d	0	
	*191	i.t.			14 h	0.07	
	192	41.0	191.961 4			0	0
	193	β^-	192.964 5	1.14 ... 0.7	32 h	0.07 ... 0.56	
77 Ir	191	37.3	190.960 9				+0.16
	192		191.963 0	0.67; 0.54; 0.24	75 d	0.2 ... 1.4	
	*192	i.t.			1.4 min	0.06	+0.17
	193	62.7	192.963 3	2.2 ... 0.5	20 h	0.3 ... 2.1	
	194	β^-	193.965 2				

Table of Isotopes (Cont.)

Z	Element A	$\alpha[\%]$ or disint.	M_u	E MeV	T	I or E_γ	μ
78 Pt	190	0.013 α	189.960 ₀	3.3	10^{12} a	0	0
	192	0.78 α	191.961 4	~ 2.6	$\sim 10^{13}$ a	0	0
	193	K	192.963 ₃		<500 a		
	*193	i.t.			4.4 d	0.013; 0.13	
	194	32.9	193.962 8			0	0
	195	33.8	194.964 8 ₂				+0.600
	196	25.3	195.964 9 ₈			0	
	197	β^-	196.967 3 ₆	0.67; 0.48; 0.47	19 h	0.08; 0.19; 0.28;	
	*197	i.t.			83 min	0.34; 0	0
	198	7.2	197.967 ₅	1.7 ... 0.8	30 min	0.07 ... 0.96	
79 Au	196	$K(\beta^-)$	195.966 5 ₅	0.3	5.6 d	0.33 (0.43)	
	197	100	196.966 5 ₅	(1.37); 0.96	2.7 d	2; 0.41	+0.14
	198	β^-	197.968 2 ₄	(0.46); 0.30	3.15 d	0.05 ... 0.2	
	199	β^-	198.968 7 ₅	0.25		0.21	
	80 Hg	196	0.15	195.965 8 ₂		0	0
81 Tl	197	K			66 h	$\frac{1}{2}; 0.08; 0.19$	0.6
	*197	i.t. (K)			24 h	$\frac{1}{2}; 0.13; 0.16$	-1.0
	198	10.0	197.966 7 ₇			0	
	199	16.8	198.968 2 ₆				+0.53
	200	23.1	199.968 3 ₄			0	
	201	13.2	200.970 3 ₂				-0.59
	202	29.8	201.970 6 ₂			0	
	203	β^-	202.972 8 ₅	0.21	47 d	0.28	
	204	6.9	203.973 4 ₈			0	
	205	β^-	204.976 ₂	1.6; 1.4	5.1 min	0.2	
82 Pb	201	201.972 ₁			12.5 d	2; 0.44	≤ 0.15
	203	29.5	202.972 ₃				+1.596
	204	β^-, K	203.973 8 ₉	0.76	~ 4 a	2; no γ	0.09
	205	70.5	204.974 4 ₆				+1.612
	206	β^-	205.976 0 ₈	1.6	4.2 min		
83 Bi	207	β^-	206.977 4 ₅	1.44	4.8 min	0.87	
	(AcC')	207	(ThC')	208	β^-	207.982 0 ₁ (2.4); 1.8; 1.6; 1.2	3.1 min 0.04 ... 2.6
	209	β^-	209.990 0 ₀	1.9	1.32 min	0.3 ... 2.4	
	82 Pb	203	K	202.973 4	52 h	0.68	
	204	1.5 α	203.973 0 ₇	2.6	1.4×10^{17} a	0	
	(RaG)	206	23.6	205.974 4 ₆		0	
	(AcD)	207	22.6	206.975 9 ₆		0	
	(ThD)	208	52.3	207.976 6 ₆			+0.584
	209	β^-	208.981 0 ₉	0.64	3.3 h		
	(RaD)	210	β^-	209.984 1 ₈	0.06; 0.018	20 a	0.047
84 Ge	(AcB)	211	β^-	210.988 8	1.39; 0.5	36.1 min	0.07 ... 0.8
	(ThB)	212	β^-	211.991 9 ₀	0.58; 0.34;	10.6 h	0.1 ... 0.4
	(RaB)	214	β^-	213.999 8	0.65; 0.59	26.8 min	0.05 ... 0.8
	83 Bi	209	100	208.980 4 ₂	α ; 4.9	3×10^6 a	
	210	$\alpha(\beta^-)$	209.984 1 ₁	β^- ; 1.17	5.0 d	1	~ 0
(RaE)	*210	$\beta^-(\alpha)$					

Table of Isotopes (Cont.)

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Element Z	A	$a[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
(AcC)	211	$\alpha(\beta^-)$	210-987 2 _o	$\alpha; 6\cdot6; 6\cdot3$	2.15 min	0.35	
(ThC)	212	β^-, α	211-991 2 _o	$\beta; 2.25$ $\alpha; 6.09; 6.05$	60.5 min	0.1 ... 2.2	
(RaC)	214	$\beta^-(\alpha)$	213-998 2 _o	$\beta^3 2^-$ $\alpha 5^-; 5^- 4$	19.7 min	0.6 ... 2.4	
84 Po	209	α	208-982 4 _o	4.88	200 a	$\frac{1}{2}$	
(RaF)	210	α	209-982 8 _o	5.30	138 d	0.8	
(AcC)	211	α	210-986 6 _o	7.44	0.6 s	0.9; 0.6	
(ThC')	212	α	211-988 8 _o	8.78	3×10^{-7} s		
(RaC)	214	α	213-995 1 _o	7.68	1.6×10^{-4} s		
(AcA)	215	$\alpha(\beta^-)$	214-999 5 _o	$\alpha; 7.38$	1.8×10^{-3} s		
(ThA)	216	$\alpha(\beta^-)$	216-001 9 _o	$\alpha; 6.78$	0.16 s		
(RaA)	218	$\alpha(\beta^-)$	218-008 9 _o	$\alpha; 6.00$	3.05 min		
85 At	210	K(α)	209-987 _o	5.52; 5.4	8.3 h	0.05 ... 2.6	
215	α	214-998 6 _o	8.0	$\sim 10^{-4}$ s			
216	α	216-002 4 _o	7.8	$\sim 3 \times 10^{-4}$ s			
218	$\alpha(\beta^-)$	218-008 5 _o	$\alpha; 6.7$	~ 2 s			
86 Rn (Em)							
(An)	219	α	219-009 5 _o	$6\cdot8; 6\cdot5; 6\cdot4$	3.92 s	0.3; 0.4	
(Tn)	220	α	220-011 4 _o	6.28	52 s	0.54	
(Rn)	222	α	222-017 5 _o	5.48	3.825 d	0.51	
87 Fr							
(AcK)	223	$\beta^-(\alpha)$	223-019 8 _o	$\beta; 1.2; \alpha; 5.3$	22 min	0.08; 0.22; 0.3	
88 Ra							
(AcX)	223	α	223-018 5 _o	$5.87 \dots 5.71$ $\dots 5.43$	11.7 d	0.03 ... 0.45	
(ThX)	224	α	224-020 2 _o	5.68; 5.45	3.64 d	0.24	
(Ra)	226	α	226-025 3 _o	$4.78; 4.60$	1600 a	0; 0.19	0
(MsTh ₁)	228	β^-	228-031 2 _o	0.053	6.7 a	0	0
89 Ac	227	$\beta^-(\alpha)$	227-027 8 _o	$80.046; \alpha 4.9$	22 a	$\frac{1}{2}$	+1.1
(MsTh ₂)	228	β^-	228-031 1 _o	2.2 ... 0.5	6.13 h	0.06 ... 1.6	
90 Th							
(RdAc)	227	α	227-027 7 _o	6.0 ... 5.7	18.2 d	0.03 ... 0.3	
(RdTh)	228	α	228-028 7 _o	$5.42; 5.34$	1.91 a	$0; 0.084; 0.13;$ 0.17; 0.22	0
	229	α	229-031 6 _o	5.0; 4.9; 4.8	7×10^3 a		
(Io)	230	α	230-033 0 _o	4.68; 4.62	8.0×10^4 a	0; 0.07 ... 0.25	0
(UY)	231	β^-	231-036 3 _o	0.3 ... 0.09	25.6 h	0.02 ... 0.3	
232	100 α	232-038 2 _o	$4.01; 3.95$	1.41×10^{10} a		0	
233	β^-	233-041 4 _o	1.23	22 min			
(UX ₁)	234	β^-	234-043 5 _o	0.19; 0.10	24.1 d	0.03 ... 0.09	
91 Pa	231	α	231-035 4 _o	5.05 ... 4.67	3.4×10^4 a	$\frac{1}{2}; 0.03 \dots 0.4$	2.0
	233	β^-	233-040 1 _o	0.57; 0.26; 0.15	27.4 d	$\frac{1}{2}; 0.02 \dots$ 0.42	+3.4
(UZ)	234	β^-	234-043 4 _o	1.1; 0.5; 0.3	6.7 h	0.04 ... 1.7	
(UX ₂)	*234	$\beta^-(i.t.)$		2.3; 1.5; 0.6	1.2 min	0.04 ... 1.8	
92 U	233	α	233-039 5 _o	4.82	1.6×10^5 a	$\frac{1}{2}; 0.04 \dots 0.1$	+0.5
(U II)	234	0.005 6 α	234-040 9 _o	4.77; 4.71	2.5×10^5 a	0; 0.05 ... 0.1	0
(AcU)	235	0.720 α	235-043 9 _o	4.56 ... 4.38	7.1×10^5 a	$\frac{1}{2}; 0.07 \dots 0.4$	-0.3
				... 4.12			

Table of Isotopes (Cont.)

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Element Z	A	$a[\%]$ or disint.	M u	E MeV	T	I or E_γ	μ
	236	α	236-045 7 _o	4.50	2.4×10^7 a	0.05	
	237	β^-	237-048 5 _o	0.25	.6-8 d	0.03 ... 0.37	
(U I)	238	99.27 α	238-050 7 _o	4.19; 4.14	4.5×10^6 a	0.048	
	239	β^-	239-054 3 _o	1.2	23.5 min	0.074	
93 Np	237	α	237-048 0 _o	4.9 ... 4.5	2.2×10^6 a	$\frac{1}{2}; 0.03 \dots 0.20$	-8.5
	238	β^-	238-050 9 _o	1.2 ... 0.3	2 d	2; 0.04 ... 1.0	
	239	β^-	239-052 9 _o	0.72 ... 0.3	2.3 d	$\frac{1}{2}; 0.05 \dots 0.33$	
94 Pu	239	α	239-052 1 _o	5.15 ... 4.9	2.4×10^4 a	$\frac{1}{2}; 0.04 \dots 0.42$	0.02
	240	α	240-053 9 _o	5.16; 5.12	6.6×10^3 a	0.045	
	241	$\beta^-(\alpha)$	241-056 7 _o	$80.02; \alpha 4.9$	13 a	$\frac{1}{2}; 0 (0.1)$	0.11
	242	α	242-058 7 _o	4.90	3.8×10^5 a		
95 Am	241	α	241-056 6 _o	5.5 ... 5.3	460 a	$\frac{1}{2}; 0.03 \dots 0.37$	+1.4
	242	β^-, K	242-059 4 _o	0.6	~ 100 a		
	*242	β^-, K			16 h	$\frac{1}{2}; 0.45; 0.042$	
96 Cm	242	α	242-058 8 _o	6.11; 6.07	163 d	0.04 ... 1.0	
	243	$\alpha(K)$	243-061 3 _o	6.06 ... 5.63	35 a	0.21; 0.23; 0.28	
	244	α	244-062 9 _o	5.80; 5.76	18 a	0.04; 0.10; 0.15	
	245	α	245-065 3 _o	5.43; 5.36	1×10^4 a	0.13; 0.17	
97 Bk	243	K(α)	243-062 9 _o	6.72; 6.55;	4.5 h	0.04 ... 0.54	
	245	K(α)	243-066 2 _o	6.37; 6.17;	50 d	0.16 ... 0.48	
	247	α	247-070 1 _o	5.67; 5.51;	10^4 a	0.08; 0.27	
	249	$\beta^-(\alpha)$	249-074 8 _o	$\beta 0.1;$ $\alpha 5.4; 5.0$	310 d	0.32	
98 Cf	250	β^-	250-078 _o	1.9; 0.9	3.2 h	1	
	246	α	246-068 7 _o	6.75; 6.71	36 h	0.04; 0.10; 0.15	
	248	α	248-072 3 _o	6.3	~ 300 d		
	249	α	249-075 7 _o	6.2; 5.9; 5.8	360 a	0.05 ... 0.34; 0.40	
	250	α	250-076 5 _o	6.02; 5.98	10 a	0.043	
	252	α (fis. Fis.)		6.11; 6.07	2.6 a	0.043; 0.10	
	254	fis. Fis.			~ 60 d		
99 Es	251	K(α)	251-079 8 _o	(6.5)	1.5 d		
	253	α	253-084 6 _o	6.63; 6.59	20 d	0.04 ... 0.43	
	254	$\beta^-(K, \alpha)$	254-088 _o	$\beta 1.0; \alpha 6.4$	38 h	0.66	
100 Fm	250	α, K	250-079 4 _o	7.4	30 min		
	252	α	252-082 6 _o	7.0	30 h		
	253	K, α		6.9	~ 5 d		
	254	α	254-087 0 _o	7.2	3 h	0.04; 0.10	
	255	α		7.0	21 h	0.06; 0.08	
	256	fis. Fis.			3 h		
101 Md	255	K, α	255-090 _o	7.3	0.5 h		
102 No	253	α		8.5	~ 10 min		
	254	α		8.8	3 s		

This is a complex and rapidly changing subject. Since the discovery of the first mesons in 1937, a great number of other particles have been found, and the whole field of particle physics and resonant states is still under constant review. The table which follows contains data on the so-called 'stable' particles, i.e. those particles which are immune to decay via the strong interaction. The rest energy of each particle is given in units of MeV, to convert to other units, use may be made of the table of energy equivalents (p.p. 80-1).

FUNDAMENTAL PARTICLES

	Name	Symbol	Rest Energy M_0/MeV	Mean lifetime τ/s	Common decay modes
Leptons	Photon	γ	0	stable	
	Neutrino	ν_e	0	stable	
		ν_μ	0	stable	
	Electron	e^\pm	0.511 004(2)	stable	
Mesons	Muon	μ^\pm	105.659(2)	$2.1994(6) \times 10^{-6}$	$e\nu\bar{\nu}$
	Pion	π^\pm	139.576(11)	$2.602(2) \times 10^{-8}$	$\mu\nu$
		π^0	134.972(12)	$0.84(10) \times 10^{-16}$	$\gamma\gamma(99\%)ye^+e^-(1\%)$
	Kaon	K^\pm	493.82(11)	$1.235(4) \times 10^{-8}$	$\mu\nu(64\%) \pi^\pm \pi^0(21\%)$ $3\pi(5\%)$
Baryons		K^0	497.76(16)	50% K_1 , 50% K_2	
		K_1	$8.62(6) \times 10^{-11}$		$\pi^+\pi^-(69\%)2\pi^0(31\%)$
		K_2	$5.38(19) \times 10^{-8}$		$ne\gamma(39\%) \pi\mu\nu(27\%)$ $3\pi^0(21\%) \pi^+\pi^-\pi^0(13\%)$
	Eta	η^0	548.8(6)		$\gamma\gamma(38\%) \pi\gamma(2\%) 3\pi^0(31\%) \pi^+\pi^-\pi^0(23\%) \pi^+\pi^-\gamma(5\%)$

29 Colour Codes in Electronics

Resistors

The colours on resistors are used to indicate the nominal value of their resistances, and the permitted tolerance on that value. In the *colour band system*, the resistor has three or four bands on it. The band at the end of the resistor indicates the first digit, the next band (working towards the centre of the resistor) indicates the second digit while the third band indicates the number of zeros which follow the two previous digits. The fourth band is used to indicate the manufacturers tolerance.

Some resistors are marked by the *body, tip and dot system* in which the first digit is indicated by the colour of the body of the resistor, the second digit by the band at one end of the resistor, and the number of zeros, by the band, or dot, in the centre of the resistor.

The colours used are as follows:

- 0 Black
- 1 Brown
- 2 Red
- 3 Orange
- 4 Yellow
- 5 Green
- 6 Blue
- 7 Violet
- 8 Grey
- 9 White

Preferred values of resistors (First two significant figs.)		
20% (no band)	10% (silver band)	5% (gold band)
10	10	10
		11
	12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
33	33	33
		36
	39	39
47	47	47
		51
	56	56
68	68	68
		75
	82	82
100	100	100

Fuses

These are often marked by coloured dots on the glass of the fuse. The rating of the fuse is given by the following code:

60 mA	Black	1.0 A	Dark blue
100 mA	Grey	1.5 A	Light blue
150 mA	Red	2.0 A	Purple
250 mA	Brown	3.0 A	White
500 mA	Yellow	5.0 A	Black and white
750 mA	Green		

Certain physical constants have special importance on account of their universality or place in fundamental theory. These are given below, first in SI and then in cgs units.

The figure in brackets which follows the final digit, is the estimated uncertainty in the last digit.

	Symbol	Quantity	Value	Multiplier and units	
				SI	cgs
	c	Speed of light in vacuo	$2.997\ 924\ 590(8)$	$10^8\ \text{m s}^{-1}$	$10^{10}\ \text{cm s}^{-1}$
	μ_0	Permeability of free space	$4\pi\ 8.84\ 19(1)$	$10^{-7}\ \text{H m}^{-1}$	—
	ϵ_0	Permittivity of free space	$1.602\ 192(7)$	$10^{-12}\ \text{F m}^{-1}$	$10^{-20}\ \text{e.m.u.}$
	e	Elementary charge	or $4.803\ 25(2)$	$10^{-19}\ \text{C}$	$10^{-10}\ \text{e.s.u.}$
	h	Planck's constant	6.626 20(5)	$10^{-34}\ \text{J s}$	$10^{-27}\ \text{erg s}$
	$h/2\pi$	Quantum charge ratio	1.054 592(8)	$10^{-34}\ \text{J s}$	$10^{-47}\ \text{erg s}$
	h/e	Fine structure constant $= \frac{e^2}{2\hbar e_c G}$	4.1370 708(14)	$10^{-15}\ \text{J s C}^{-1}$	$10^{-7}\ \text{e.m.u.}$
	α	Gravitational constant	or $1.379\ 523(5)$	—	$10^{-17}\ \text{e.s.u.}$
	$1/\alpha$	Impedance of free space	7.297 351(11)	10^{-3}	10^{-3}
	G		1.370 360(2)	10^2	10^2
	Z_0		6.673(3)	$10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	$10^{-8}\ \text{dyn cm}^2\ \text{g}^{-2}$
			3.767 304(1)	$10^2\ \text{Ohm}$	$10^{11}\ \text{e.m.u.}$
General constants	m_e	Electron rest mass	9.109 56(5)	$10^{-31}\ \text{kg}$	$10^{-28}\ \text{g}$
	$m_e c^2$	Electron rest energy	8.187 26(6)	$10^{-14}\ \text{J}$	$10^{-7}\ \text{erg}$
	e/m_e	Electron charge-mass ratio	or $5.110\ 041(16)$	$10^{-1}\ \text{MeV}$	—
			1.758 803(5)	$10^{11}\ \text{C kg}^{-1}$	$10^7\ \text{e.m.a.}$
Electron	λ_e	Compton wave length of electron	or $5.272\ 759(16)$	—	$10^{17}\ \text{e.s.u.}$
	r_e	Classical radius of electron	2.426 310(7)	$10^{-12}\ \text{m}$	$10^{-10}\ \text{cm}$
			2.817 939(13)	$10^{-15}\ \text{m}$	$10^{-13}\ \text{m}$

The Fundamental Combinatorics (Contd.)

		Symbol	Quantity	Value	SI	cgs	Multiplier and units
Proton	m_p	Proton rest mass	1.672 614(11)	10^{-27} kg	10^{-24} g	10^{-3} erg	
	$m_p c^2$	Proton rest energy	1.503 271(15) or 9.382 59(5)	10^{-10} J	10^{-13} e.m.u.	—	
	e/m_p	Proton charge-mass ratio	9.578 97(11) or 2.871 70(3)	10^2 MeV 10^7 C kg $^{-1}$	10^{13} e.s.u.	10^{13} e.m.u.	
	λ_{cp}	Proton Compton wavelength	1.321 441(9)	10^{-15} m	10^{-13} cm		
	γ	Gyromagnetic ratio	2.675 197(8)	10^8 s $^{-1}$ T $^{-1}$	10^4 e.m.u.		
	y'	Gyromagnetic ratio (uncorrected for diamagnetism)	2.675 127(8)	10^8 s $^{-1}$ T $^{-1}$	10^4 e.m.u.		
	m_n	Neutron rest mass	1.674 920(11)	10^{-27} kg	10^{-24} g	10^{-3} erg	
	$m_n c^2$	Neutron rest energy	1.505 343(15). or 9.395 53(5)	10^{-10} J 10^2 MeV	10^{-13} e.m.u.	—	
	R	Rydberg constant	1.097 373 11(1)	10^7 m $^{-1}$	10^5 cm $^{-1}$		
	a_0	Bohr radius	5.291 772(8)	10^{-11} m	10^{-9} cm		
Neutron	μ	Bohr magneton	9.274 10(6)	10^{-24} J T $^{-1}$	10^{-21} e.m.u.		
	μ_n	Nuclear magneton	5.050 95(5)	10^{-27} J T $^{-1}$	10^{-24} e.m.u.		
	$\mu/\hbar c$	Zeeman splitting constant	4.668 60(7)	10^1 m $^{-1}$ T $^{-1}$	10^{-5} e.m.u.		
	N	Avogadro constant	6.022 17(4) or 6.022 17(4)	10^{23} mol $^{-1}$	10^{23} mol $^{-1}$	10^{23} mol $^{-1}$	
Matter in Bulk	F	Faraday	9.648 67(5)	10^{26} kg mol $^{-1}$	10^3 e.s.u. mol $^{-1}$	10^{14} e.s.u. mol $^{-1}$	
	V_0	Normal volume of perfect gas	2.892 599(16)	10^4 C mol $^{-1}$	10^4 cm 3 mol $^{-1}$	10^4 cm 3 mol $^{-1}$	
	R	Gas constant	2.241 36(30)	10^0 J K $^{-1}$ mol $^{-1}$	10^7 erg K $^{-1}$ mol $^{-1}$	10^7 erg K $^{-1}$ mol $^{-1}$	
	k	Boltzmann constant	8.314 3(3)	10^{-23} J K $^{-1}$	10^{-16} erg K $^{-1}$	10^{-16} erg K $^{-1}$	
	σ	Stefan's constant	1.380 62(6)	10^{-8} W m $^{-2}$ K $^{-4}$	10^{-5} erg m $^{-2}$ K $^{-4}$	10^{-5} erg m $^{-2}$ K $^{-4}$	