

Dimensional Analysis – Background

Website: <http://ts.nist.gov/ts/hdocs/230/235/appxc/appxc.htm>

Appendix C of NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices

General Tables of Units of Measurement

These tables have been prepared for the benefit of those requiring tables of units for occasional ready reference. In Section 4 of this appendix, the tables are carried out to a large number of decimal places and exact values are indicated by underlining. In most of the other tables only a limited number of decimal places are given, thus making the tables better adapted to the average user.

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1. TABLES OF METRIC UNITS OF MEASUREMENT

In the metric system of measurement, designations of multiples and sub-divisions of any unit may be arrived at by combining with the name of the unit the prefixes deka, hecto, and kilo meaning, respectively, 10, 100, and 1000, and deci, centi, and milli, meaning, respectively, one-tenth, one-hundredth, and one-thousandth. In some of the following metric tables, some

such multiples and sub-divisions have not been included for the reason that these have little, if any currency in actual usage.

In certain cases, particularly in scientific usage, it becomes convenient to provide for multiples larger than 1 000 and for subdivisions smaller than one-thousandth. Accordingly, the following prefixes have been introduced and these are now generally recognized:

yotta, (Y),	meaning 10^{24}	deci, (d),	meaning 10^{-1}
zetta, (Z),	meaning 10^{21}	centi, (c),	meaning 10^{-2}
exa, (E),	meaning 10^{18}	milli, (m),	meaning 10^{-3}
peta, (P),	meaning 10^{15}	micro, (u),	meaning 10^{-6}
tera, (T),	meaning 10^{12}	nano, (n),	meaning 10^{-9}
giga, (G),	meaning 10^9	pico, (p),	meaning 10^{-12}
mega, (M),	meaning 10^6	femto, (f),	meaning 10^{-15}
kilo, (k),	meaning 10^3	atto, (a),	meaning 10^{-18}
hecto, (h),	meaning 10^2	zepto, (z),	meaning 10^{-21}
deka, (da),	meaning 10^1	yocto, (y),	meaning 10^{-24}

Units of Length

10 millimeters (mm)	= 1 centimeter (cm)
10 centimeters	= 1 decimeter (dm) = 100 millimeters
10 decimeters	= 1 meter (m) = 1000 millimeters
10 meters	= 1 dekameter (dam)
10 dekameters	= 1 hectometer (hm) = 100 meters
10 hectometers	= 1 kilometer (km) = 1000 meters

Units of Area

100 square millimeters (mm ²)	= 1 square centimeter (cm ²)
100 square centimeters	= 1 square decimeter (dm ²)
100 square decimeters	= 1 square meter (m ²)
100 square meters	= 1 square dekameter (dam ²) = 1 are
100 square dekameters	= 1 square hectometer (hm ²) = 1 hectare (ha)
100 square hectometers	= 1 square kilometer (km ²)

Units of Liquid Volume

10 milliliters (mL)	= 1 centiliter (cL)
10 centiliters	= 1 deciliter (dL) = 100 milliliters
10 deciliters	= 1 liter ^l = 1000 milliliters

10 liters	= 1 dekaliter (daL)
10 dekaliters	= 1 hectoliter (hL) = 100 liters
10 hectoliters	= 1 kiloliter (kL) = 1000 liters

Units of Volume

1000 cubic millimeters (mm ³)	= 1 cubic centimeter (cm ³)
1000 cubic centimeters	= 1 cubic decimeter (dm ³)
	= 1 000 000 cubic millimeters
1000 cubic decimeters	= 1 cubic meter (m ³)
	= 1 000 000 cubic centimeters
	= 1 000 000 000 cubic millimeters

Units of Mass

10 milligrams (mg)	= 1 centigram (cg)
10 centigrams	= 1 decigram (dg) = 100 milligrams
10 decigrams	= 1 gram (g) = 1000 milligrams
10 grams	= 1 dekagram (dag)
10 dekagrams	= 1 hectogram (hg) = 100 grams
10 hectograms	= 1 kilogram (kg) = 1000 grams
1000 kilograms	= 1 megagram (Mg) or 1 metric ton(t)

2. TABLES OF U.S. UNITS OF MEASUREMENT²

In these tables where foot or mile is underlined, it is survey foot or U.S. statute mile rather than international foot or mile that is meant.

Units of Length

12 inches (in)	= 1 foot (ft)
3 <u>feet</u>	= 1 yard (yd)
16-1/2 feet	= 1 rod (rd), pole, or perch
40 rods	= 1 furlong (fur) = 660 <u>feet</u>
8 furlongs	= 1 U.S. statute mile (mi) = 5280 <u>feet</u>
1852 meters	= 6076.115 49 feet (approximately)
	= 1 international nautical mile

Units of Area³

144 square inches (in ²)	= 1 square foot (ft ²)
9 square feet	= 1 square yard (yd ²)

272-1/4 square <u>feet</u>	= 1296 square inches
160 square rods	= 1 square rod (sq rd)
640 acre	= 1 acre = 43 560 square feet
1 <u>mile</u> square	= 1 square <u>mile</u> (mi ²)
6 <u>miles</u> square	= 1 section of land
	= 1 township
	= 36 sections = 36 square <u>miles</u>

Units of Volume³

1728 cubic inches (in ³)	= 1 cubic foot (ft ³)
27 cubic feet	= 1 cubic yard (yd ³)

Gunter's or Surveyors Chain Units of Measurement

0.66 <u>foot</u> (ft)	= 1 link (li)
100 links	= 1 chain (ch)
	= 4 rods = 66 <u>feet</u>
80 chains	= 1 U.S. statute mile (mi)
	= 320 rods = 5280 <u>feet</u>

Units of Liquid Volume⁴

4 gills (gi)	= 1 pint (pt) = 28.875 cubic inches
2 pints	= 1 quart (qt) = 57.75 cubic inches
4 quarts	= 1 gallon (gal) = 231 cubic inches
	= 8 pints = 32 gills

Apothecaries Units of Liquid Volume

60 minims (min or m)	= 1 fluid dram (fl dr or f^{ss})
	= 0.225 6 cubic inch
8 fluid drams	= 1 fluid ounce (fl oz or f^{ss})
	= 1.804 7 cubic inches
16 fluid ounces	= 1 pint (pt or O)
	= 28.875 cubic inches
	= 128 fluid drams
2 pints	= 1 quart (qt) = 57.75 cubic inches
	= 32 fluid ounces = 256 fluid drams
4 quarts	= 1 gallon (gal) = 231 cubic inches
	= 128 fluid ounces = 1024 fluid drams

Units of Dry Volume⁵

2 pints (pt)	= 1 quart (qt) = 67.200 6 cubic inches
8 quarts	= 1 peck (pk) = 537.605 cubic inches
	= 16 pints
4 pecks	= 1 bushel (bu) = 2150.42 cubic inches
	= 32 quarts

Avoirdupois Units of Mass⁶

[The "grain" is the same in avoirdupois, troy, and apothecaries units of mass.]

27-11/32 grains	= 1 dram (dr)
16 drams	= 1 ounce (oz)
	= 437-1/2 grains
16 ounces	= 1 pound (lb)
	= 256 drams
	= 7000 grains
100 pounds	= 1 hundredweight (cwt) ⁷
20 hundredweights	= 1 ton
	= 2000 pounds ⁷

In "gross" or "long" measure, the following values are recognized:

112 pounds	= 1 gross or long hundredweight ⁷
20 gross or long hundredweights	= 1 gross or long ton
	= 2240 pounds ⁷

Troy Units of Mass

[The "grain" is the same in avoirdupois, troy, and apothecaries units of mass.]

24 grains	= 1 pennyweight (dwt)
20 pennyweights	= 1 ounce troy (oz t) = 480 grains
12 ounces troy	= 1 pound troy (lb t)
	= 240 pennyweights = 5760 grains

Apothecaries Units of Mass

[The "grain" is the same in avoirdupois, troy, and apothecaries units of mass.]

20 grains	= 1 scruple (s ap or $\mathfrak{ʒ}$)
3 scruples	= 1 dram apothecaries (dr ap or $\mathfrak{ʒ}$)
	= 60 grains
8 drams apothecaries	= 1 ounce apothecaries (oz ap or $\mathfrak{ʒ}$)
	= 24 scruples = 480 grains
12 ounces apothecaries	= 1 pound apothecaries (lb ap)
	= 96 drams apothecaries
	= 288 scruples = 5760 grains

3. NOTES ON BRITISH UNITS OF MEASUREMENT

In Great Britain, the yard, the avoirdupois pound, the troy pound, and the apothecaries pound are identical with the units of the same names used in the United States. The tables of British linear measure, troy mass, and apothecaries mass are the same as the corresponding United States tables, except for the British spelling "drachm" in the table of apothecaries mass. The table of British avoirdupois mass is the same as the United States table up to 1 pound; above that point the table reads:

14 pounds	= 1 stone
2 stones	= 1 quarter = 28 pounds
4 quarters	= 1 hundredweight = 112 pounds
20 hundredweight	= 1 ton = 2240 pounds

The present British gallon and bushel--known as the "Imperial gallon" and "Imperial bushel" are, respectively, about 20 percent and 3 percent larger than the United States gallon and bushel. The Imperial gallon is defined as the volume of 10 avoirdupois pounds of water under specified conditions, and the Imperial bushel is defined as 8 Imperial gallons. Also, the subdivision of the Imperial gallon as presented in the table of British apothecaries fluid measure differs in two important respects from the corresponding United States subdivision, in that the Imperial gallon is divided into 160 fluid ounces (whereas the United States gallon is divided into 128 fluid ounces), and a "fluid scruple" is included. The full table of British measures of capacity (which are used alike for liquid and for dry commodities) is as follows

4 gills	= 1 pint
2 pints	= 1 quart
4 quart	= 1 gallon
2 gallons	= 1 peck
8 gallons (4 pecks)	= 1 bushel
8 bushels	= 1 quarter

The full table of British apothecaries measure is as follows

20 minims = 1 fluid scruple
 3 fluid scruples = 1 fluid drachm
 = 60 minims
 8 fluid drachm = 1 fluid ounce
 20 fluid ounces = 1 pint
 8 pints = 1 gallon (160 fluid ounces)

4. TABLES OF UNITS OF MEASUREMENT
 (all underlined figures are exact)

Units of Length - International Measure⁸

Units	Inches	Feet	Yards	Miles	Centimeters	Meters
1 inch =	<u>1</u>	0.083 333 33	0.027 777 78	0.000 015 782 83	<u>2.54</u>	<u>0.025 4</u>
1 foot =	<u>12</u>	<u>1</u>	0.333 333 3	0.000 189 393 9	<u>30.48</u>	<u>0.304 8</u>
1 yard =	<u>36</u>	<u>3</u>	<u>1</u>	0.000 568 181 8	<u>91.44</u>	<u>0.914 4</u>
1 mile =	<u>63 360</u>	<u>5 280</u>	<u>1 760</u>	<u>1</u>	<u>160 934.4</u>	<u>1609.344</u>
1 centimeter =	0.393 700 8	0.032 808 40	0.010 936 13	0.000 006 213 712	<u>1</u>	<u>0.01</u>
1 meter =	39.370 08	3.280 840	1.093 613	0.000 621 371 2	<u>100</u>	<u>1</u>

Units of Length - Survey Measure⁸

Units	Links	Feet	Rods	Chains	Miles	Meters
1 link =	<u>1</u>	<u>0.66</u>	<u>0.04</u>	<u>0.01</u>	<u>0.000 125</u>	0.201 168 4
1 foot =	1.515 152	<u>1</u>	0.060 606 06	0.015 151 52	0.000 189 393 9	0.304 800 6
1 rod =	<u>25</u>	<u>16.5</u>	<u>1</u>	<u>0.25</u>	<u>0.003 125</u>	5.029 210
1 chain =	<u>100</u>	<u>66</u>	<u>4</u>	<u>1</u>	<u>0.0125</u>	20.116 84
1 mile =	<u>8 000</u>	<u>5 280</u>	<u>320</u>	<u>80</u>	<u>1</u>	1609.347
1 meter =	4.970 960	3.280 833	0.198 838 4	0.049 709 60	0.000 621 369 9	<u>1</u>

Units of Area - International Measure⁹
 (all underlined figures are exact)

Units		Square Inches	Square Feet	Square Yards
1 square inch	=	1	0.006 944 444	0.000 771 604 9
1 square foot	=	<u>144</u>	1	0.111 111 1
1 square yard	=	<u>1296</u>	<u>9</u>	1
1 square mile	=	<u>4 014 489 600</u>	<u>27 878 400</u>	<u>3 097 600</u>
1 square centimeter	=	0.155 000 3	0.001 076 391	0.000 119 599 0
1 square meter	=	1550.003	10.763 91	1.195 990

Units		Square Miles	Square Centimeters	Square Meters
1 square inch	=	0.000 000 000 249 097 7	<u>6.451 6</u>	<u>0.000 645 16</u>
1 square foot	=	0.000 000 035 870 06	<u>929.030 4</u>	<u>0.092 903 04</u>
1 square yard	=	0.000 000 322 830 6	<u>8361.273 6</u>	<u>0.836 127 36</u>
1 square mile	=	1	<u>25 899 881 103.36</u>	<u>2 589 988.110 336</u>
1 square centimeter	=	0.000 000 000 038 610 22	1	<u>0.0001</u>
1 square meter	=	0.000 000 386 102 2	<u>10 000</u>	1

Units of Area - Survey Measure⁹

Units		Square Feet	Square Rods	Square Chains	Acres
1 square foot	=	1	0.003 673 095	0.000 229 568 4	0.000 022 956 84
1 square rod	=	<u>272.25</u>	1	<u>0.062 5</u>	<u>0.006 25</u>
1 square chain	=	<u>4356</u>	<u>16</u>	1	<u>0.1</u>
1 acre	=	<u>43 560</u>	<u>160</u>	<u>10</u>	1
1 square mile	=	<u>27 878 400</u>	<u>102 400</u>	<u>6400</u>	<u>640</u>
1 square meter	=	10.763 87	0.039 536 70	0.002 471 044	0.000 247 104 4
1 hectare	=	107 638.7	395.367 0	24.710 44	2.471 044

Units		Square Miles	Square Meters	Hectares
1 square foot	=	0.000 000 035 870 06	0.092 903 41	0.000 009 290 341
1 square rod	=	<u>0.000 009 765 625</u>	25.292 95	0.002 529 295
1 square chain	=	<u>0.000 156 25</u>	404.687 3	0.040 468 73
1 acre	=	<u>0.001 562 5</u>	4 046.873	0.404 687 3
1 square mile	=	1	2 589 998	258.999 8
1 square meter	=	0.000 000 386 100 6	1	<u>0.000 1</u>
1 hectare	=	0.003 861 006	<u>10 000</u>	1

Units of Volume
(all underlined figures are exact)

Units	Cubic Inches	Cubic Feet	Cubic Yards
1 cubic inch =	<u>1</u>	0.000 578 703 7	0.000 021 433 47
1 cubic foot =	<u>1728</u>	<u>1</u>	0.037 037 04
1 cubic yard =	<u>46 656</u>	<u>27</u>	<u>1</u>
1 cubic centimeter =	0.061 023 74	0.000 035 314 67	0.000 001 307 951
1 cubic decimeter =	61.023 74	0.035 314 67	0.001 307 951
1 cubic meter =	61 023.74	35.314 67	1.307 951

Units	Milliliters (Cubic Centimeters)	Liters (Cubic Decimeters)	Cubic Meters
1 cubic inch =	<u>16.387 064</u>	<u>0.016 387 064</u>	<u>0.000 016 387 064</u>
1 cubic foot =	<u>28 316.846 592</u>	<u>28.316 846 592</u>	<u>0.028 316 846 592</u>
1 cubic yard =	<u>764 554.857 984</u>	<u>764.554 857 984</u>	<u>0.764 554 857 984</u>
1 cubic centimeter =	<u>1</u>	<u>0.001</u>	<u>0.000 001</u>
1 cubic decimeter =	<u>1000</u>	<u>1</u>	<u>0.001</u>
1 cubic meter =	<u>1 000 000</u>	<u>1000</u>	<u>1</u>

Units of Capacity or Volume - Dry Volume Measure

Units	Dry Pints	Dry Quarts	Pecks	Bushels
1 dry pint =	<u>1</u>	<u>0.5</u>	<u>0.062 5</u>	<u>0.015 625</u>
1 dry quart =	<u>2</u>	<u>1</u>	<u>0.125</u>	<u>0.031 25</u>
1 peck =	<u>16</u>	<u>8</u>	<u>1</u>	<u>0.25</u>
1 bushel =	<u>64</u>	<u>32</u>	<u>4</u>	<u>1</u>
1 cubic inch =	0.029 761 6	0.014 880 8	0.001 860 10	0.000 465 025
1 cubic foot =	51.428 09	25.714 05	3.214 256	0.803 563 95
1 liter =	1.816 166	0.908 083 0	0.113 510 4	0.028 377 59
1 cubic meter =	1 816.166	908.083 0	113.510 4	28.377 59

Units		Cubic Inches	Cubic Feet	Liters	Cubic Meters
1 dry pint	=	<u>33.600 312 5</u>	0.019 444 63	0.550 610 5	0.000 550 610 5
1 dry quart	=	<u>67.200 625</u>	0.038 889 25	1.101 221	0.001 101 221
1 peck	=	<u>537.605</u>	0.311 114	8.809 768	0.008 809 768
1 bushel	=	<u>2 150.42</u>	1.244 456	35.239 07	0.035 239 07
1 cubic inch	=	1	0.000 578 703 7	0.016 387 06	0.000 016 387 06
1 cubic foot	=	<u>1728</u>	1	28.316 85	0.028 316 85
1 liter	=	61.023 74	0.035 314 67	1	<u>0.001</u>
1 cubic meter	=	61 023.74	35.314 67	<u>1000</u>	<u>1</u>

Units of Capacity or Volume - Liquid Volume Measure
(all underlined figures are exact)

Units		Minims	Fluid Drams	Fluid Ounces	Gills
1 minim	=	1	0.016 666 67	0.002 083 333	0.000 520 833 3
1 fluid dram	=	<u>60</u>	1	<u>0.125</u>	<u>0.031 25</u>
1 fluid ounce	=	<u>480</u>	<u>8</u>	1	<u>0.25</u>
1 gill	=	<u>1920</u>	<u>32</u>	<u>4</u>	1
1 liquid pint	=	<u>7680</u>	<u>128</u>	<u>16</u>	<u>4</u>
1 liquid quart	=	<u>15 360</u>	<u>256</u>	<u>32</u>	<u>8</u>
1 gallon	=	<u>61 440</u>	<u>1024</u>	<u>128</u>	<u>32</u>
1 cubic inch	=	265.974 0	4.432 900	0.554 112 6	0.138 528 1
1 cubic foot	=	459 603.1	7660.052	957.506 5	239.376 6
1 milliliter	=	16.230 73	0.270 512 2	0.033 814 02	0.008 453 506
1 liter	=	16 230.73	270.512 2	33.814 02	8.453 506

Units		Liquid Pints	Liquid Quarts	Gallons	Cubic Inches
1 minim	=	0.000 130 208 3	0.000 065 104 17	0.000 016 276 04	0.003 759 766
1 fluid dram	=	<u>0.007 812 5</u>	<u>0.003 906 25</u>	<u>0.000 976 562 5</u>	0.225 585 94
1 fluid ounce	=	<u>0.062 5</u>	<u>0.031 25</u>	<u>0.007 812 5</u>	<u>1.804 687 5</u>
1 gill	=	<u>0.25</u>	<u>0.125</u>	<u>0.031 25</u>	<u>7.218 75</u>
1 liquid pint	=	1	<u>0.5</u>	<u>0.125</u>	<u>28.875</u>
1 liquid quart	=	2	1	<u>0.25</u>	<u>57.75</u>
1 gallon	=	8	4	1	<u>231</u>
1 cubic inch	=	0.034 632 03	0.017 316 02	0.004 329 004	1
1 cubic foot	=	59.844 16	29.922 08	7.480 519	<u>1728</u>
1 milliliter	=	0.002 113 376	0.001 056 688	0.000 264 172 1	0.061 023 74
1 liter	=	2.113 376	1.056 688	0.264 172 1	61.023 74

Units		Cubic Feet	Milliliters	Liters
1 minim	=	0.000 002 175 790	0.061 611 52	0.000 061 611 52
1 fluid dram	=	0.000 130 547 4	3.696 691	0.003 696 691
1 fluid ounce	=	0.001 044 379	29.573 53	0.029 573 53
1 gill	=	0.004 177 517	118.294 1	0.118 294 1
1 liquid pint	=	0.016 710 07	473.176 5	0.473 176 5
1 liquid quart	=	0.033 420 14	946.352 9	0.946 352 9
1 gallon	=	0.133 680 6	3785.412	3.785 412
1 cubic inch	=	0.000 578 703 7	16.387 06	0.016 387 06
1 cubic foot	=	<u>1</u>	28 316.85	28.316 85
1 milliliter	=	0.000 035 314 67	<u>1</u>	<u>0.001</u>
1 liter	=	0.035 314 67	<u>1000</u>	<u>1</u>

Units of Mass Not Less Than Avoirdupois Ounces
(all underlined figures are exact)

Units	Avoirdupois Ounces	Avoirdupois Pounds	Short Hundred-weights	Short tons
1 avoirdupois ounce =	<u>1</u>	<u>0.0625</u>	<u>0.000 625</u>	<u>0.000 031 25</u>
1 avoirdupois pound =	<u>16</u>	<u>1</u>	<u>0.01</u>	<u>0.000 5</u>
1 short hundredweight =	<u>1600</u>	<u>100</u>	<u>1</u>	<u>0.05</u>
1 short ton =	<u>32 000</u>	<u>2000</u>	<u>20</u>	<u>1</u>
1 long ton =	<u>35 840</u>	<u>2240</u>	<u>22.4</u>	<u>1.12</u>
1 kilogram =	35.273 96	2.204 623	0.022 046 23	0.001 102 311
1 metric ton =	35 273.96	2204.623	22.046 23	1.102 311

Units	Long Tons	Kilograms	Metric Tons
1 avoirdupois ounce =	0.000 027 901 79	<u>0.028 349 523 125</u>	<u>0.000 028 349 523 125</u>
1 avoirdupois pound =	0.000 446 428 6	<u>0.453 592 37</u>	<u>0.000 453 592 37</u>
1 short hundredweight =	0.044 642 86	<u>45.359 237</u>	<u>0.045 359 237</u>
1 short ton =	0.892 857 1	<u>907.184 74</u>	<u>0.907 184 74</u>
1 long ton =	<u>1</u>	<u>1016.046 908 8</u>	<u>1.016 046 908 8</u>
1 kilogram =	0.000 984 206 5	<u>1</u>	<u>0.001</u>
1 metric ton =	0.984 206 5	<u>1000</u>	<u>1</u>

Units of Mass Not Greater Than Pounds or Kilograms

(all underlined figures are exact)

Units	Grains	Apothecaries Scruples	Pennyweights	Avoirdupois Drams
1 grain =	<u>1</u>	<u>0.05</u>	0.041 666 67	0.036 571 43
1 apoth. scruple =	<u>20</u>	<u>1</u>	0.833 333 3	0.731 428 6
1 pennyweight =	<u>24</u>	<u>1.2</u>	<u>1</u>	0.877 714 3
1 avdp. dram =	<u>27.343 75</u>	<u>1.367 187 5</u>	1.139 323	<u>1</u>
1 apoth. dram =	<u>60</u>	<u>3</u>	<u>2.5</u>	2.194 286
1 avdp. ounce =	<u>437.5</u>	<u>21.875</u>	18.229 17	<u>16</u>
1 apoth. or troy oz. =	<u>480</u>	<u>24</u>	<u>20</u>	17.554 29
1 apoth. or troy pound =	<u>5760</u>	<u>288</u>	<u>240</u>	210.651 4
1 avdp. pound =	<u>7000</u>	<u>350</u>	291.666 7	<u>256</u>
1 milligram =	0.015 432 36	0.000 771 617 9	0.000 643 014 9	0.000 564 383 4
1 gram =	15.432 36	0.771 617 9	0.643 014 9	0.564 383 4
1 kilogram =	15432.36	771.617 9	643.014 9	564.383 4

Units	Apothecaries Drams	Avoirdupois Ounces	Apothecaries or Troy Ounces	Apothecaries or Troy Pounds
1 grain =	0.016 666 67	0.002 285 714	0.002 083 333	0.000 173 611 1
1 apoth. scruple =	0.333 333 3	0.045 714 29	0.041 666 67	0.003 472 222
1 pennyweight =	<u>0.4</u>	0.054 857 14	<u>0.05</u>	0.004 166 667
1 avdp. dram =	0.455 729 2	<u>0.062 5</u>	0.56 966 15	0.004 747 179
1 apoth. dram =	<u>1</u>	0.137 142 9	<u>0.125</u>	0.010 416 67
1 avdp. ounce =	7.291 667	<u>1</u>	0.911 458 3	0.075 954 86
1 apoth. or troy ounce =	<u>8</u>	1.097 143	<u>1</u>	0.083 333 333
1 apoth. or troy pound =	<u>96</u>	13.165 71	<u>12</u>	<u>1</u>
1 avdp. pound =	116.666 7	<u>16</u>	14.583 33	1.215 278
1 milligram =	0.000 257 206 0	0.000 035 273 96	0.000 032 150 75	0.000 002 679 229
1 gram =	0.257 206 0	0.035 273 96	0.032 150 75	0.002 679 229
1 kilogram =	257.206 0	35.273 96	32.150 75	2.679 229

Units	Avoirdupois Pounds	Milligrams	Grams	Kilograms
1 grain =	0.000 142 857 1	<u>64.798 91</u>	<u>0.064 798 91</u>	<u>0.000 064 798 91</u>
1 apoth. scruple =	0.002 857 143	<u>1295.978 2</u>	<u>1.295 978 2</u>	<u>0.001 295 978 2</u>
1 pennyweight =	0.003 428 571	<u>1555.173 84</u>	<u>1.555 173 84</u>	<u>0.001 555 173 84</u>
1 avdp. dram =	0.003 906 25	<u>1771.845 195 312 5</u>	<u>1.771 845 195 312 5</u>	<u>0.001 771 845 195 312 5</u>
1 apoth. dram =	0.008 571 429	<u>3887.934 6</u>	<u>3.887 934 6</u>	<u>0.003 887 934 6</u>
1 avdp. ounce =	<u>0.062 5</u>	<u>28 349.523 125</u>	<u>28.349 523 125</u>	<u>0.028 349 523 125</u>
1 apoth. or troy ounce =	0.068 571 43	<u>31 103.476 8</u>	<u>31.103 476 8</u>	<u>0.031 103 476 8</u>
1 apoth. or troy pound =	0.822 857 1	<u>373 241.721 6</u>	<u>373.241 721 6</u>	<u>0.373 241 721 6</u>
1 avdp. pound =	1	<u>453 592.37</u>	<u>453.592 37</u>	<u>0.453 592 37</u>
1 milligram =	0.000 002 204 623	1	<u>0.001</u>	<u>0.000 001</u>
1 gram =	0.002 204 623	<u>1000</u>	1	<u>0.001</u>
1 kilogram =	2.204 623	1 000 000	1000	1

5. TABLES OF EQUIVALENTS

In these tables it is necessary to differentiate between the "international foot" and the "survey foot;" the survey foot is underlined. When the name of a unit is enclosed in brackets (thus, [1 hand] . . .), this indicates (1) that the unit is not in general current use in the United States, or (2) that the unit is believed to be based on "custom and usage" rather than on formal authoritative definition. Equivalents involving decimals are, in most instances, rounded off to the third decimal place except where they are exact, in which cases these exact equivalents are so designated. The equivalents of the imprecise units "tablespoon" and "teaspoon" are rounded to the nearest milliliter.

UNITS OF LENGTH

	0.1 nanometer (exactly).
	0.000 1 micrometer (exactly).
angstrom (\AA) ¹⁰ -----	0.000 000 1 millimeter (exactly).
	0.000 000 004 inch.
	120 fathoms (exactly).
1 cable's length-----	720 feet (exactly).
	219 meters.
1 centimeter (cm)-----	0.393 7 inch.

1 chain (ch)----- (Gunter's or surveyors)	66 feet (exactly). 20.1168 meters
1 decimeter (dm)-----	3.937 inches.
1 dekameter (dam)-----	32.808 feet.
1 fathom-----	6 feet (exactly). 1.828 8 meters.
1 foot (ft)-----	0.304 8 meter (exactly).
1 furlong (fur)-----	10 chains (surveyors) (exactly). 660 feet (exactly). 1/8 U.S. statute mile (exactly). 201.168 meters.
[1 hand]-----	4 inches.
1 inch (in)-----	2.54 centimeters (exactly).
1 kilometer (km)-----	0.621 mile.
1 league (land)-----	3 U.S. statute miles (exactly). 4.828 kilometers.
1 link (li) (Gunter's or surveyors)----	0.66 foot (exactly). 0.201 168 meter.
1 meter (m)-----	39.37 inches. 1.094 yards.
1 micrometer-----	0.001 millimeter (exactly). 0.000 039 37 inch.
1 mil-----	0.001 inch (exactly). 0.025 4 millimeter (exactly).

1 mile (mi) (U.S. statute) ¹¹ -----	5280 survey feet (exactly). 1.609 kilometers.
1 mile (mi) (international)-----	5280 international feet (exactly).
1 mile (mi) (international nautical) ¹² -----	1.852 kilometers (exactly). 1.151 survey miles.
1 millimeter (mm)-----	0.039 37 inch.
1 nanometer (nm)-----	0.001 micrometer (exactly). 0.000 000 039 37 inch.
1 Point (typography)-----	0.013 837 inch (exactly). 1/72 inch (approximately). 0.351 millimeter.
1 rod (rd), pole, or perch-----	16 1/2 feet (exactly). 5.029 2 meters.
1 yard (yd)-----	0.914 4 meter (exactly).

UNITS OF AREA

1 acre ¹³ -----	43 560 square feet (exactly). 0.405 hectare.
1 are-----	119.599 square yards. 0.025 acre.
1 hectare-----	2.471 acre.
[1 square (building)]-----	100 square feet.
1 square centimeter (cm ²)-----	0.155 square inch.

1 square decimeter (dm ²)-----	15.500 square inches.
1 square foot (ft ²)-----	929.030 square centimeters.
1 square inch (in ²)-----	6.451 6 square centimeters (exactly).
1 square kilometer (km ²)-----	247.104 acre. 0.386 square mile.
1 square meter (m ²)-----	1.196 square yards. 10.764 square feet.
1 square mile (mi ²)-----	258.999 hectares.
1 square millimeter (mm ²)-----	0.002 square inch.
1 square rod (rd ²), sq pole, or sq perch-----	25.293 square meters.
1 square yard (yd ²)-----	0.836 square meter.

UNITS OF CAPACITY OR VOLUME

1 barrel (bbl), liquid-----	31 to 42 gallons. ¹⁴
1 barrel (bbl), standard for fruits, vegetables, and other dry----- commodities, except cranberries	7056 cubic inches. 105 dry quarts. 3.281 bushels, struck measure.
1 barrel (bbl), standard, cranberry----	5 826 cubic inches. 86 45/64 dry quarts. 2.709 bushels, struck measure.
1 bushel (bu) (U.S.) struck measure--- -	2150.42 cubic inches (exactly). 35.239 liters.

[1 bushel, heaped (U.S.)]-----	2 747.715 cubic inches. 1.278 bushels, struck measure. ¹⁵
[1 bushel (bu) (British Imperial) (struck measure)]-----	1.032 U.S. bushels, struck measure 2219.36 cubic inches.
1 cord (cd) (firewood)-----	128 cubic feet (exactly).
1 cubic centimeter (cm ³)-----	0.061 cubic inch.
1 cubic decimeter (dm ³)-----	61.024 cubic inches.
1 cubic foot (ft ³)-----	7.481 gallons. 28.316 cubic decimeters.
1 cubic inch (in ³)-----	0.554 fluid ounce. 4.433 fluid drams. 16.387 cubic centimeters.
1 cubic meter (m ³)-----	1.308 cubic yards.
1 cubic yard (yd ³)-----	0.765 cubic meter.
1 cup, measuring-----	8 fluid ounces (exactly). 237 milliliters. 1/2 liquid pint (exactly).
1 dekaliter (daL)-----	2.642 gallons. 1.135 pecks.
1 dram, fluid (or liquid) (fl dr or <i>f</i> ⁵) (U.S.)-----	1/8 fluid ounce (exactly). 0.226 cubic inch. 3.697 milliliters. 1.041 British fluid drachms.
[1 drachm, fluid (fl dr) (British)]----	0.961 U.S. fluid dram. 0.217 cubic inch. 3.552 milliliters.

1 gallon (gal) (U.S.)-----	231 cubic inches (exactly). 3.785 liters. 0.833 British gallon. 128 U.S. fluid ounces (exact-ly).
[1 gallon (gal) (British Imperial)]----	277.42 cubic inches. 1.201 U.S. gallons. 4.546 liters. 160 British fluid ounces (exactly).
1 gill (gi)-----	7.219 cubic inches. 4 fluid ounces (exactly). 0.118 liter.
1 hectoliter (hL)-----	26.418 gallons. 2.838 bushels.
1 liter (1 cubic decimeter exactly)----	1.057 liquid quarts. 0.908 dry quart. 61.025 cubic inches
1 milliliter (mL)-----	0.271 fluid dram. 16.231 minims. 0.061 cubic inch.
1 ounce, fluid (or liquid) (fl oz or $f^{\frac{3}{4}}$)(U.S.)-----	1.805 cubic inches. 29.573 milliliters. 1.041 British fluid ounces.-
[1 ounce, fluid (fl oz) (British)]----	0.961 U.S. fluid ounce. 1.734 cubic inches. 28.412 milliliters.
1 peck (pk)-----	8.810 liters.
1 pint (pt), dry-----	33.600 cubic inches. 0.551 liter.
-	

1 pint (pt), liquid-----	28.875 cubic inches exactly. 0.473 liter.
1 quart (qt), dry (U.S.)-----	67.201 cubic inches. 1.101 liters. 0.969 British quart.
1 quart (qt), liquid (U.S.)-----	57.75 cubic inches (exactly). 0.946 liter. 0.833 British quart.
[1 quart (qt) (British)]-----	69.354 cubic inches. 1.032 U.S. dry quarts. 1.201 U.S. liquid quarts.
1 tablespoon, measuring-----	3 teaspoons (exactly). 15 milliliters. 4 fluid drams. 1/2 fluid ounce (exactly).
1 teaspoon, measuring-----	1/3 tablespoon (exactly). 5 milliliters. 1-1/3 fluid drams. ¹⁶
1 water ton (English)-----	270.91 U.S. gallons. 224 British Imperial gallons. (exactly).

UNITS OF MASS

1 assay ton ¹⁷ (AT)-----	29.167 grams.
1 carat (c)-----	200 milligrams (exactly). 3.086 grains.
1 dram apothecaries (dr ap or ʒ)---	60 grains (exactly).

	3.888 grams.
1 dram avoirdupois (dr avdp)-----	27-11/32 (= 27.344) grains. 1.777 grams.
1 gamma (γ)-----	1 microgram (exactly).
1 grain-----	64.798 91 milligrams (exactly).
1 gram (g)-----	15.432 grains. 0.035 ounce, avoirdupois.
1 hundredweight, gross or long ¹⁸ (gross cwt)-----	112 pounds (exactly). 50.802 kilograms.
1 hundredweight, gross or short (cwt or net cwt)-----	100 pounds (exactly). 45.359 kilograms.
1 kilogram (kg)-----	2.205 pounds.
1 microgram (μg) [the Greek letter mu in combination with the letter g]---	0.000 001 gram (exactly).
1 milligram (mg)-----	0.015 grain.
	437.5 grains (exactly).
1 ounce, avoirdupois (oz avdp)----- -	0.911 troy or apothecaries ounce. 28.350 grams.
1 ounce, troy or apothecaries (oz t or oz ap or \mathfrak{z})-----	480 grains (exactly). 1.097 avoirdupois ounces. 31.103 grams.
1 pennyweight (dwt)-----	1.555 grams.
1 point-----	0.01 carat.

	2 milligrams.
	7000 grains (exactly).
1 pound, avoirdupois (lb avdp)-----	1.215 troy or apothecaries pounds.
-	453.592 37 grams (exactly).
1 pound, troy or apothecaries	5760 grains (exactly).
(lb t or lb ap)-----	0.823 avoirdupois pound.
	373.242 grams.
1 scruple (s ap or \mathfrak{s})-----	20 grains (exactly).
	1.296 grams.
	2240 pounds (exactly).
1 ton, gross or long ¹⁹ -----	1.12 net tons (exactly).
	1.016 metric tons.
	2204.623 pounds.
1 ton, metric (t)-----	0.984 gross ton.
	1.102 net tons.
	2000 pounds (exactly).
1 ton, net or short-----	0.893 gross ton.
	0.907 metric ton.

¹ By action of the 12th General Conference on Weights and Measures (1964) the liter is a special name for the cubic decimeter.

² This section lists units of measurement that have traditionally been used in the United States. In keeping with the Omnibus Trade and Competitiveness Act of 1988, the ultimate objective is to make the International System of Units the primary measurement system used in the United States.

³ Squares and cubes of customary but not of metric units are sometimes expressed by the use of abbreviations rather than symbols. For example, sq ft means square foot, and cu ft means cubic foot.

⁴ When necessary to distinguish the liquid pint or quart from the dry pint or quart, the word "liquid" or the abbreviation "liq" should be used in combination with the name or abbreviation of the liquid unit.

⁵ When necessary to distinguish the dry pint or quart from the liquid pint or quart, the word "dry" should be used

in combination with the name or abbreviation of the dry unit.

⁶ When necessary to distinguish the avoirdupois dram from the apothecaries dram, or to distinguish the avoirdupois dram or ounce from the fluid dram or ounce, or to distinguish the avoirdupois ounce or pound from the troy or apothecaries ounce or pound, the word "avoirdupois" or the abbreviation "avdp" should be used in combination with the name or abbreviation of the avoirdupois unit.

⁷ When the terms "hundredweight" and "ton" are used unmodified, they are commonly understood to mean the 100-pound hundredweight and the 2000-pound ton, respectively; these units may be designated "net" or "short" when necessary to distinguish them from the corresponding units in gross or long measure.

⁸ One international foot = 0.999 998 survey foot (exactly)
One international mile = 0.999 998 survey mile (exactly)

Note: 1 survey foot = 1200/3937 meter (exactly)
1 international foot = 12 x 0.0254 meter (exactly)
1 international foot = 0.0254 x 39.37 survey foot (exactly)

⁹ One square survey foot = 1.000 004 square international feet
One square survey mile = 1.000 004 square international miles

¹⁰ The angstrom is basically defined as 10^{-10} meter.

¹¹ The term "statute mile" originated with Queen Elizabeth I who changed the definition of the mile from the Roman mile of 5000 feet to the statute mile of 5280 feet. The international mile and the U.S. statute mile differ by about 3 millimeters although both are defined as being equal to 5280 feet. The international mile is based on the international foot (0.3048 meter) whereas the U.S. statute mile is based on the survey foot (1200/3937 meter).

¹² The international nautical mile of 1 852 meters (6 076.115 49...feet) was adopted effective July 1, 1954, for use in the United States. The value formerly used in the United States was 6 080.20 feet = 1 nautical (geographical or sea) mile.

¹³ The question is often asked as to the length of a side of an acre of ground. An acre is a unit of area containing 43 560 square feet. It is not necessarily square, or even rectangular. But, if it is square, then the length of a side is equal to $\sqrt{43\,560} = 208.710+$ feet.

¹⁴ There are a variety of "barrels" established by law or usage. For example, Federal taxes on fermented liquors are based on a barrel of 31 gallons; many State laws fix the "barrel for liquids" as 31-1/2 gallons; one State fixes a 36-gallon barrel for cistern measurement; Federal law recognizes a 40-gallon barrel for "proof spirits"; by custom, 42 gallons comprise a barrel of crude oil or petroleum products for statistical purposes, and this is recognized "for liquids" by four States.

¹⁵ Frequently recognized as 1-1/4 bushels, struck measure.

¹⁶ The equivalent "1 teaspoon = 1-1/3 fluid drams" has been found by the Bureau to correspond more closely with the actual capacities of "measuring" and silver teaspoons than the equivalent "1 teaspoon = 1 fluid dram", which is given by a number of dictionaries.

¹⁷ Used in assaying. The assay ton bears the same relation to the milligram that a ton of 2000 pounds avoirdupois bears to the ounce troy; hence the mass in milligrams of precious metal obtained from one assay ton

of ore gives directly the number of troy ounces to the net ton.

¹⁸ The gross or long ton and hundredweight are used commercially in the United States to only a very limited extent, usually in restricted industrial fields. The units are the same as the British "ton" and "hundredweight".

¹⁹ The gross or long ton and hundredweight are used commercially in the United States to only a very limited extent, usually in restricted industrial fields. The units are the same as the British "ton" and "hundredweight".

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