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THE INTERNATIONAL
METRIC SYSTEM
OF WEIGHTS AND
MEASURES

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THE INTERNATIONAL METRIC SYSTEM OF WEIGHTS AND MEASURES¹

ABSTRACT

This publication presents a brief account of the international metric system of weights and measures. Its purpose is to give such information as will adequately answer some of the more simple questions addressed to the bureau on this subject and to set forth a working knowledge of the system. The publication gives a brief account of the origin of the metric system, information concerning the International Bureau of Weights and Measures, the international standards, and the national prototype standards of the United States. A synopsis of the system is given which shows the derivation of the primary units, their interrelation one with another, the method of forming the multiples and submultiples, the abbreviations used, comparisons of the units with those of our customary system of weights and measures, and tables of equivalents. The status of the metric system in the United States is shown by congressional enactments and departmental orders.

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¹ Revised by William Parry.

I. INTRODUCTION

The following was prepared to answer some of the more simple questions addressed to the Bureau of Standards in regard to the metric system of weights and measures and its use.

The essential features of the system were embodied in a report made to the French National Assembly by the Academy of Sciences in 1791. A number of other nations were invited to cooperate with France in establishing the new system, and Denmark, Holland, Spain, Switzerland, and several other countries were represented on an international commission which met in Paris in 1799 to accept the metric standards constructed under the direction of the French Institute. These standards were known as the standards "of the archives."

Although the metric system very soon attracted the favorable attention of other nations, it was not until 40 years later that its use became general in France. Since 1840 its use has rapidly spread until now it is either obligatory or permissive in practically every civilized country in the world. Its use was made "lawful throughout the United States" by act of Congress in 1866,² and at the same time provision was made to supply every State in the Union with a set of metric weights and measures.

No organized effort had been made up to this time to supply the different countries with authentic copies of the metric prototypes which were preserved in the archives of France. In order to meet the demand for accurate standards whose relation to one another would be known with the highest precision, metric conventions were held in Paris in 1870 and 1872, which were attended by official delegates from about 30 countries. At these conferences committees were appointed to investigate the best form and material for the proposed new standards. In 1875 a treaty was signed at Paris by 17 of the principal nations of the world, the United States being among the number, which provided for the permanent organization of an International Bureau of Weights and Measures under the direction of an International Committee. The most important work of the International Committee was to provide for the construction of a sufficient number of platinum-iridium meters and kilograms to meet the demand of the interested nations. The comparison of all these standards with one another and with the original meter and kilogram was made at the International Bureau which had been established near Paris on neutral territory ceded to the International Committee by the French Government. Following the completion of this work in 1889, a certain meter and a certain kilogram were selected and adopted as the international prototype standards, displacing the meter and the kilogram "of the archives" which had heretofore been regarded as the standards. Prototype meters and kilograms were distributed by lot to the countries signatory to the Convention of 1875. The international prototype meter and kilogram are preserved in a special underground vault at the International Bureau and are accessible only to the International Committee.

² R. S. 3569.

II. STANDARDS OF LENGTH AND MASS

The United States secured two meters (Nos. 27 and 21) and two kilograms (Nos. 20 and 4), which are now preserved at the Bureau of Standards at Washington, D. C. Meter No. 27 and kilogram No. 20 serve as the primary standards of length and mass of the United States. It is the plan of the International Committee to intercompare all the national meters and kilograms with the international prototypes at regular intervals, or whenever considered necessary. Meter No. 27 has twice been taken to the International Bureau of Weights and Measures for verification, the first time in 1903 and again in 1921. No sensible change has taken place. In each instance the bar was taken personally by a representative of the Bureau of Standards, and the utmost care was exercised for its protection against damage. Meter No. 21, used as a secondary standard, was taken to the International Bureau of Weights and Measures in August, 1931, for recomparison. Neither of the kilograms has yet been returned to the International Bureau of Weights and Measures for recomparison.

III. MAINTENANCE OF THE INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES

At the present time the International Bureau of Weights and Measures is maintained jointly by the following named 32 countries, under the terms of the Metric Convention, a treaty agreed upon May 20, 1875: Argentina; Austria; Belgium; Brazil; Bulgaria; Canada; Chile; Czechoslovakia; Denmark; Finland; France and Algeria; Germany; Great Britain; Hungary; Irish Free State; Italy; Japan; Mexico; Norway; Peru; Poland; Portugal; Rumania; Serbs, Croats, and Slovenes; Siam; Spain; Sweden; Switzerland; Union of Soviet Socialist Republics; United States; and Uruguay.

IV. SYNOPSIS OF THE SYSTEM

The units of the metric system at the outset were all derived from the unit of length, the meter, which was defined as one ten-millionth part of the earth's quadrant. The unit of volume, the cubic decimeter or the liter, was defined as a cube of one-tenth meter on a side; and the unit of mass, the kilogram, was defined as the mass of a cubic decimeter, or liter, of pure water when at the temperature of its maximum density, 4° C.

It was found, however, that masses could be compared with a higher degree of accuracy than that with which volumes could be determined, and it was, therefore, preferable to have a material standard of mass specifically defined, rather than one derived from the unit of length, through the unit of volume. A specific mass, the international prototype kilogram, was, therefore, adopted as the standard of mass, and the unit of volume, the liter, was then redefined in terms of the standard of mass; the liter being defined as the volume of a kilogram of pure water at the temperature of its maximum density.

The present basis of the metric system of weights and measures may, therefore, be summarized as follows: (1) A material standard of length, the international prototype meter; (2) a material standard of mass, the international prototype kilogram; (3) a standard of volume, the cubic decimeter, derived from the unit of length; and (4) a standard of volume, the liter, derived from the unit of mass.

Some advantages claimed for the metric system are:

1. The decimal relation between the units.
2. The simple relation of the units of length, area, volume, and weight to one another.
3. The uniform and self-defining names of units.

1. FORMATION OF MULTIPLES AND SUBMULTIPLES

The metric tables are formed by combining the words "METER," "GRAM," and "LITER" with the six numerical prefixes, as in the following tables:

PREFIXES		MEANING		UNITS
milli-	= one thousandth	$\frac{1}{1000}$	0.001	"meter" for length,
centi-	= one hundredth	$\frac{1}{100}$.01	
deci-	= one tenth	$\frac{1}{10}$.1	
Unit = one			1	"gram" for weight or mass,
deka-	= ten	$\frac{10}{1}$	10	"liter" for capacity.
hecto-	= one hundred	$\frac{100}{1}$	100	
kilo-	= one thousand	$\frac{1000}{1}$	1,000	

2. UNITS OF LENGTH

millimeter =	0.001 meter.
centimeter =	.01 meter.
decimeter =	.1 meter.
METER =	1 meter.
dekameter =	10 meters.
hectometer =	100 meters.
kilometer =	1,000 meters.

Where the *mile* is used in England and the United States for measuring distances, the *kilometer* (1,000 meters) is used in metric

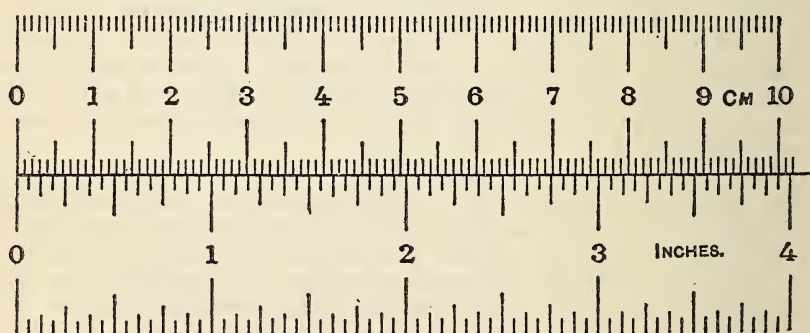


FIGURE 1.—Comparison scale: 10 centimeters and 4 inches. (Actual size)

countries. The kilometer is about five-eighths of a mile. There are about 1,609 meters in a statute mile, 20 meters in a chain, and 5 meters in a rod.

The *meter* is used for dry goods, merchandise, engineering construction, building, and other purposes where the *yard* and *foot* are used. The meter is about 10 per cent longer than the yard.

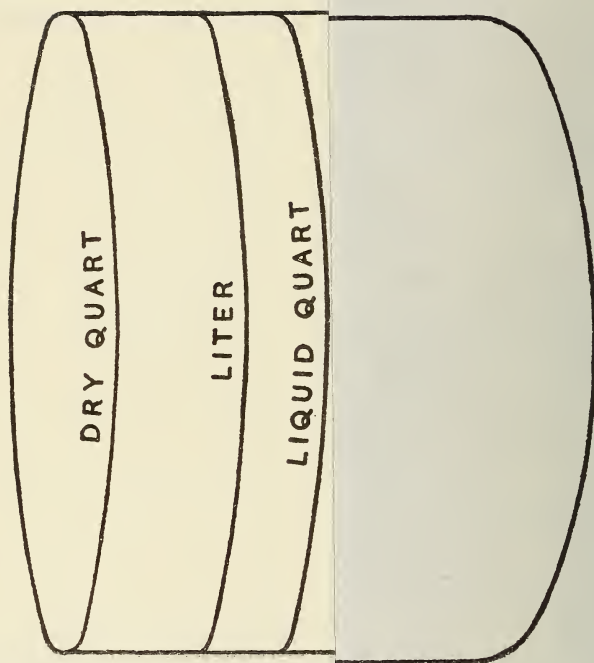


FIGURE 2.—*Comparison of the dry quart, liter, and liquid quart*
This figure is used to show comparative volumes, but is not intended to show
actual shapes
107212°—32. (Face p. 5.)

The *centimeter* and *millimeter* are used instead of the *inch* and its fractions in machine construction and similar work. The centimeter, as its name shows, is the hundredth of a meter. It is used in cabinet work, in expressing sizes of paper, books, and in many other cases where the inch is used. The centimeter is about two-fifths of an inch and the millimeter about one twenty-fifth of an inch. The millimeter is divided for finer work into tenths, hundredths, and thousandths.

3. UNITS OF AREA

The table of areas is formed by squaring the length measures, as in our common system. For land measure 10 meters square is called an "ARE" (meaning "area"). The side of one *are* is about 33 feet. The HECTARE is 100 meters square, and, as its name indicates, is 100 ares, or about $2\frac{1}{2}$ acres. An *acre* is about 0.4 hectare. A standard United States *quarter section* contains approximately 65 hectares. A *square kilometer* contains 100 hectares.

For smaller measures of surface the *square meter* is used. The square meter is about 20 per cent larger than the *square yard*. For still smaller surfaces the *square centimeter* and *square millimeter* are used. A *square inch* contains about $6\frac{1}{2}$ square centimeters. For exact values, see pp. 10, 11.

4. UNITS OF VOLUME

The units of volume are the liter and the cubic decimeter and their various multiples and subdivisions. The liter is slightly larger than the cubic decimeter, the relation, as exactly as it has been determined,³ being

$$1 \text{ liter} = 1.000027 \text{ cubic decimeters.}$$

The liter and its one-thousandth part, the milliliter, are ordinarily employed as the units of volume in measurements of volume and density of liquids. The milliliter is often improperly designated as the cubic centimeter or the "cc." The correct designation is "ml." The cubic decimeter and its multiples and subdivisions are employed in determinations of volume derived from linear measurements.

The cubic measures are the cubes of the linear units. The *cubic meter* (sometimes called the *stère*, meaning "solid") is the unit of volume. The cubic meter is used in place of the cubic yard and is about 30 per cent larger. This is used for "cuts and fills" in grading land, measuring timber, expressing contents of tanks and reservoirs, flow of rivers, dimensions of stone, tonnage of ships, and other places where the cubic yard and foot are used. The thousandth part of the cubic meter is called the *cubic decimeter*. (See table of capacity units.)

For small volumes of liquids the *milliliter* (ml) is used. This volume of water weighs a *gram*, which is the unit of weight or mass. There are about 16 milliliters in a cubic inch. The milliliter is the unit of volume used by chemists as well as in pharmacy, medicine, surgery, and other technical work. One thousand milliliters make one liter.

³ Trav. et Mém. du Bureau International des Poids et Mesures, XIV; 1910.

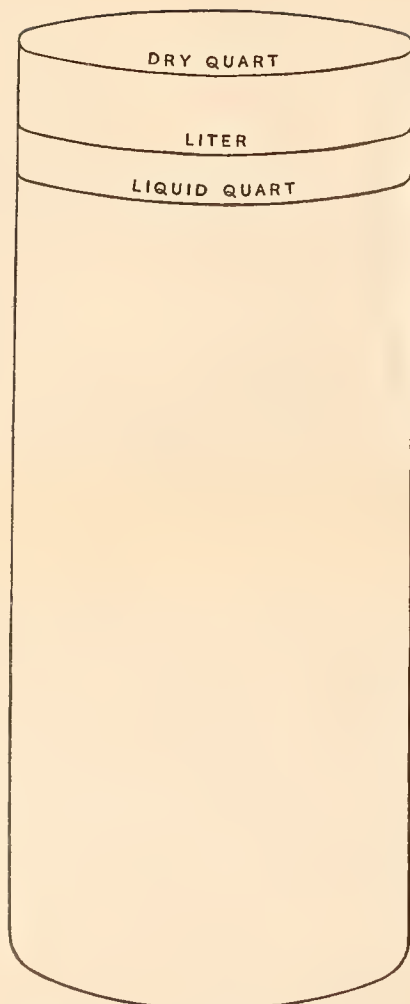


FIGURE 2.—Comparison of the dry quart, liter, and liquid quart

This figure is used to show comparative volumes, but is not intended to show actual shapes

5. UNITS OF CAPACITY

milliliter	=	0.001	liter
centiliter	=	.01	liter
deciliter	=	.1	liter
LITER	=	1	liter
dekaliter	=	10	liters
hectoliter	=	100	liters
kiloliter	=	1,000	liters

The *hectoliter* (100 liters) serves the same purposes as the United States *bushel* (2,150.42 cubic inches), and is equal to nearly 3 bushels. A *peck* is about 9 liters. The liter is used for measurements commonly given in the *gallon*, or in the liquid or dry *quarts*, a liter being 5 per cent larger than our liquid quart and 10 per cent smaller than the dry quart. A *liter* of water at the temperature of its greatest density, 4° C., weighs exactly a *kilogram*, that is, 1,000 grams. A thousand liters of water weigh 1 metric ton.

6. UNITS OF WEIGHT (OR MASS)

milligram	=	0.001	gram
centigram	=	.01	gram
decigram	=	.1	gram
GRAM	=	1	gram
dekagram	=	10	grams
hectogram	=	100	grams
kilogram	=	1,000	grams

Measurements commonly expressed in *long tons* or *short tons* are stated in *metric tons* (1,000 kilograms). The metric ton falls between

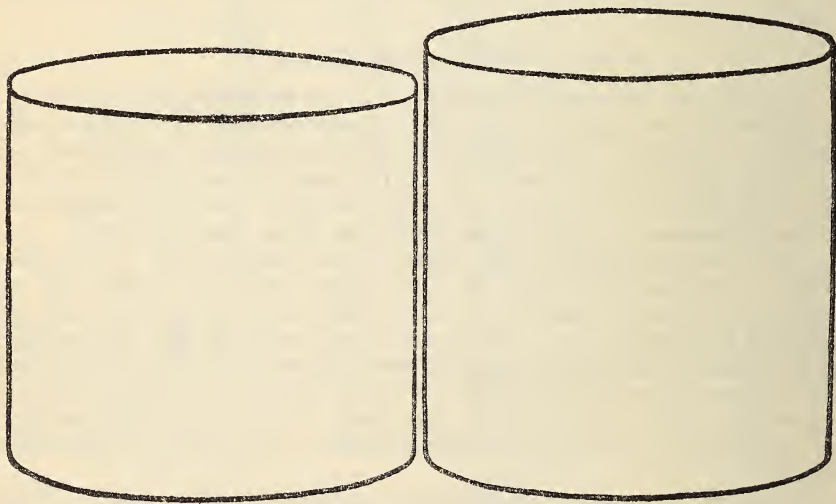


FIGURE 3.—Relative size of 2-pound and 1-kilogram (brass) weights

our long and short tons and serves the purpose of both. The *kilogram* and “half kilo” serve for everyday trade, the latter being about 10 per cent larger than the pound. The kilogram is approximately

2.2 pounds. The *gram* and its multiples and divisions are used for the same purposes as ounces, pennyweights, drams, scruples, and grains.



FIGURE 4.—Relative size of avoirdupois ounce, 30-gram, and troy ounce (brass) weights

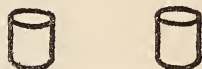


FIGURE 5.—Relative size of gram and scruple (brass) weights

V. STATUS OF THE INTERNATIONAL METRIC SYSTEM IN THE UNITED STATES

1. CONSTITUTIONAL AUTHORITY TO FIX STANDARDS

"The Congress shall have power to * * * fix the standard of weights and measures." (Constitution of the United States, Art. 1, sec. 8, par. 5.)

2. THE METRIC SYSTEM LEGALIZED

"It shall be lawful throughout the United States of America to employ the weights and measures of the metric system, * * *." (Revised Statutes of the United States, sec. 3569.)

3. THE METRIC STANDARDS ADOPTED AS FUNDAMENTAL

"* * * the office of weights and measures * * * will in the future regard the international prototype meter and kilogram as fundamental standards, and the customary units, the yard and the pound, will be derived therefrom in accordance with the act of July 28, 1866." (Order approved by the Secretary of the Treasury, April 5, 1893.)

4. METRIC BALANCES FURNISHED CERTAIN POST OFFICES

"The Postmaster General shall furnish to the post offices exchanging mails with foreign countries, and to such other offices as he may deem expedient, postal balances denominated in grams of the metric system, fifteen grams of which shall be the equivalent for postal puposes, of one-half ounce avoirdupois, and so on in progression." (Revised Statutes of the United States, sec. 3880.)

5. METRIC WEIGHTS USED FOR CERTAIN COINS

"* * * the weight of the half-dollar shall be twelve grams and one-half of a gram; the quarter-dollar and the dime shall be, respectively, one-half and one-fifth of the weight of said half-dollar." (Revised Statutes of the United States, sec. 3513.)

6. CONGRESS PROVIDES METRIC STANDARDS FOR THE STATES OF THE UNION, LAND-GRANT AGRICULTURAL COLLEGES, AND THE SMITHSONIAN INSTITUTION

"Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, authorized and directed to furnish to each State, to be delivered to the governor thereof, one set of the standard weights and measures of the metric system for the use of the States, respectively." (Joint resolution of Congress approved July 27, 1866.)

*"Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, directed to cause a complete set of all the weights and measures adopted as standards to be delivered to the governor of each State in the Union, for the use of agricultural colleges in the States, respectively, which have received a grant of lands from the United States, and also one set of the same for the use of the Smithsonian Institution: * * *."* (Joint resolution of Congress, approved March 3, 1881.)

7. UNITED STATES JOINS IN ESTABLISHING INTERNATIONAL BUREAU

"The high contracting parties engage to establish and maintain, at their common expense, a scientific and permanent international bureau ⁴ of weights and measures, the location of which shall be at Paris." (Extract from convention of 1875, signed for the United States by the United States ambassador to France.)

8. CONGRESS ADOPTS THE METRIC UNITS FOR ELECTRICAL MEASURES

It was enacted by the Senate and House of Representatives that the international electrical units based on the metric system shall be the legal units of electrical measure in the United States. (See Revised Statutes of the United States, Supplement, vol. 2, chap. 131, 1894.)

9. METRIC SYSTEM REQUIRED IN THE MEDICAL WORK OF THE WAR DEPARTMENT, THE NAVY DEPARTMENT, AND THE BUREAU OF THE PUBLIC HEALTH SERVICE OF THE TREASURY DEPARTMENT

(a) "Pharmacy management. * * *

"(b) Records.

"1. In time of peace and, so far as practicable, in time of war all prescriptions will be written in the metric system. * * *." (Army Regulations, 1929, Regulation 40-590, par. 18, sub-par. 18-b (1).)

(b) "The metric system of weights and measures shall hereafter be employed in the Medical Department of the Navy." (Order approved by the Secretary of the Navy, April 15, 1878.)⁵

(c) "Officers shall, for all official, medical, and pharmacal purposes, make use of the metric system of weights and measures." (Regulations of the U. S. Public Health Service, 1931, sec. 856.)

⁴ This bureau has the custody of the international standards of the metric system, to which all metric prototypes of the world are referred for verification. It was established and is maintained jointly by various governments, a list of those now contributing to its support is given on page 3.

⁵ The metric system is now used exclusively only in the medical prescription work of the Bureau of Medicine and Surgery.

10. METRIC CARAT ADOPTED AS UNIT FOR DIAMONDS AND OTHER PRECIOUS STONES

"Beginning July 1, 1913, the Bureau of Standards will recognize the international metric carat of 200 milligrams as the unit of weight for diamonds and other precious stones and will use this unit for the purposes of certification of all carat weights submitted to the bureau for test." (Circular No. 43, Bureau of Standards, issued November 1, 1913.)

"On and after July 1, 1913, the unit of weight for imported diamonds, pearls, and other precious stones will be the metric carat of 200 milligrams.

"Collectors at ports now equipped with scales for weighing precious stones will make requisition for a new set of weights based upon such carat." (Treasury Department order, June 17, 1913, to collectors and other officers of the customs.)

11. METRIC SYSTEM OPTIONAL IN PORTO RICO

"SECTION 1.—That the metric system of weights and measures, and the imperial system customarily used in the United States in so far as the same is described by this act, are hereby recognized and established in Porto Rico for use in all industrial and commercial transactions, * * *"

(Act No. 135, approved, August 18, 1913.)

12. METRIC SYSTEM MADE THE LEGAL SYSTEM IN THE PHILIPPINE ISLANDS

"The weights and measures to be used throughout the Philippine Islands are those of the metric system, with the following units: * * *

"The metric system of weights and measures, with its recognized scales, shall be used in all contracts, deeds, and other instruments publicly and officially attested, and in all official documents; and, except as hereinbelow provided, only weights and measures of the metric system shall be officially sealed and licensed.

"In the purchase and sale of manufactured lumber the English system of measures may be employed; and in ordering commodities or articles from abroad such weights and measures may be employed as are commonly used in the country to which the order is sent or from which the goods are shipped." (Administrative Code, 1917, vol. 2, Art. IX, p. 8, secs. 32 and 33.)

VI. EQUIVALENTS OF CERTAIN UNITS

These values are given to a larger number of decimal places than will be found in the tables following.

Centimeter	=	0.3937 inch.
Meter	=	39.37 inches (exactly).
Square centimeter	=	.1549997 square inch.
Square meter	=	1.195985 square yards.
Hectare	=	2.47104 acres.
Cubic meter	=	1.3079428 cubic yards.
Liter	=	.264178 gallon.
Liter	=	1.05671 liquid quarts.
Liter	=	.908102 dry quart.
Hectoliter	=	2.83782 bushels.
Gram	=	15.432356 grains.
Kilogram	=	2.204622341 pounds, avoirdupois.
Inch	=	2.540005 centimeters.
Yard	=	.9144018 meter.
Square inch	=	6.451626 square centimeters.
Square yard	=	.8361307 square meter.
Acre	=	.404687 hectare.
Cubic yard	=	.7645594 cubic meter.
Gallon	=	3.785332 liters.
Liquid quart	=	.946333 liter.
Dry quart	=	1.101198 liters.
Bushel	=	35.23833 liters.
Grain	=	.064798918 gram.
Pound, avoirdupois	=	.4535924277 kilogram.

VII. COMPARISON OF METRIC AND CUSTOMARY UNITS FROM 1 TO 9

1. LENGTH

Inches (in.)	Millimeters (mm)	Feet (ft.)	Meters (m)	Yards (yd.)	Meters (m)	Rods (rd.)	Meters (m)	U. S. miles (mi.)	Kilometers (km)
0. 03937=1		1=0. 304801		1=0. 914402		0. 198838=1		0. 621370=1	
. 07874=2		2= . 609601		2=1. 828804		. 397677=2		1. 242740=2	
. 11811=3		3= . 914402		3=2. 743205		. 596515=3		1. 864110=3	
. 15748=4		4=1. 219202		4=3. 657607		. 795354=4		2. 485480=4	
. 19685=5		5=1. 524003		5=4. 572009		. 994192=5		3. 106850=5	
. 23622=6		6=1. 828804		6=5. 486411		1. 193030=6		3. 728220=6	
. 27559=7		7=2. 133604		7=6. 400813		1. 391869=7		4. 349590=7	
. 31496=8		8=2. 438405		8=7. 315215		1. 590707=8		4. 970960=8	
. 35433=9		9=2. 743205		9=8. 229616		1. 789545=9		5. 592330=9	
1= 25. 4001		3. 28083=1		1. 093611=1		1= 5. 02921		1= 1. 609347	
2= 50. 8001		6. 56167=2		2. 187222=2		2=10. 05842		2= 3. 218694	
3= 76. 2002		9. 84250=3		3. 280833=3		3=15. 08763		3= 4. 828042	
4=101. 6002		13. 12333=4		4. 374444=4		4=20. 11684		4= 6. 437389	
5=127. 0003		16. 40417=5		5. 468056=5		5=25. 14605		5= 8. 046736	
6=152. 4003		19. 68500=6		6. 561667=6		6=30. 17526		6= 9. 656083	
7=177. 8004		22. 96583=7		7. 655278=7		7=35. 20447		7=11. 265431	
8=203. 2004		26. 24667=8		8. 748889=8		8=40. 23368		8=12. 874778	
9=228. 6005		29. 52750=9		9. 842500=9		9=45. 26289		9=14. 484125	

2. AREA

Square inches (sq. in.)	Square centimeters (cm ²)	Square feet (sq. ft.)	Square meters (m ²)	Square yards (sq. yd.)	Square meters (m ²)	Acres (A.)	Hectares (ha)	Square miles (sq. mi.)	Square kilometers (km ²)
0. 15500=1		1=0. 09290		1=0. 8361		1=0. 4047		0. 3861=1	
. 31000=2		2= . 18581		2=1. 6723		2= . 8094		. 7722=2	
. 46500=3		3= . 27871		3=2. 5084		3=1. 2141		1. 1583=3	
. 62000=4		4= . 37161		4=3. 3445		4=1. 6187		1. 5444=4	
. 77500=5		5= . 46452		5=4. 1807		5=2. 0234		1. 9305=5	
. 93000=6		6= . 55742		6=5. 0168		6=2. 4281		2. 3166=6	
1. 08500=7		7= . 65032		7=5. 8529		7=2. 8328		2. 7027=7	
1. 24000=8		8= . 74323		8=6. 6890		8=3. 2375		3. 0888=8	
1. 39500=9		9= . 83613		9=7. 5252		9=3. 6422		3. 4749=9	
1= 6. 452		10. 764=1		1. 1960=1		2. 471=1		1= 2. 5900	
2=12. 903		21. 528=2		2. 3920=2		4. 942=2		2= 5. 1800	
3=19. 355		32. 292=3		3. 5880=3		7. 413=3		3= 7. 7700	
4=25. 807		43. 055=4		4. 7839=4		9. 884=4		4=10. 3690	
5=32. 258		53. 819=5		5. 9799=5		12. 355=5		5=12. 9500	
6=38. 710		64. 583=6		7. 1759=6		14. 826=6		6=15. 5400	
7=45. 161		75. 347=7		8. 3719=7		17. 297=7		7=18. 1300	
8=51. 613		86. 111=8		9. 5679=8		19. 768=8		8=20. 7200	
9=58. 065		96. 875=9		10. 7639=9		22. 239=9		9=23. 3100	

3. VOLUME

Cubic inches (cu. in.)	Cubic centimeters (cm ³)	Cubic feet (cu. ft.)	Cubic meters (m ³)	Cubic yards (cu. yd.)	Cubic meters (m ³)	Cubic inches (cu. in.)	Liters (l)	Cubic feet (cu. ft.)	Liters (l)
0. 06102=1		1=0. 028317		1=0. 7646		1=0. 0163867		1= 28. 316	
. 12205=2		2= . 056634		2=1. 5291		2= . 0327734		2= 56. 633	
. 18307=3		3= . 084951		3=2. 2937		3= . 0491602		3= 84. 949	
. 24409=4		4= . 113268		4=3. 0582		4= . 0655469		4=113. 265	
. 30512=5		5= . 141585		5=3. 8228		5= . 0819336		5=141. 581	
. 36614=6		6= . 169902		6=4. 5874		6= . 0983203		6=169. 898	
. 42716=7		7= . 198219		7=5. 3519		7= . 1147070		7=198. 214	
. 48819=8		8= . 226536		8=6. 1165		8= . 1310938		8=226. 530	
. 54921=9		9= . 254853		9=6. 8810		9= . 1474805		9=254. 846	
1= 16. 3872		35. 314=1		1. 3079=1		61. 025=1		0. 035315=1	
2= 32. 7743		70. 629=2		2. 6159=2		122. 050=2		. 070631=2	
3= 49. 1615		105. 943=3		3. 9238=3		183. 075=3		. 105946=3	
4= 65. 5486		141. 258=4		5. 2318=4		244. 100=4		. 141262=4	
5= 81. 9358		176. 572=5		6. 5397=5		305. 125=5		. 176577=5	
6= 98. 3230		211. 887=6		7. 8477=6		366. 150=6		. 211892=6	
7=114. 7101		247. 201=7		9. 1556=7		427. 175=7		. 247208=7	
8=131. 0973		282. 516=8		10. 4635=8		488. 200=8		. 282523=8	
9=147. 4845		317. 830=9		11. 7715=9		549. 225=9		. 317839=9	

4. CAPACITY—LIQUID MEASURE

U. S. fluid drams (fl. dr.)	Milli- liters (ml)	U. S. fluid ounces (fl. oz.)	Milli- liters (ml)	U. S. liquid pints (pt.)	Liters (l)	U. S. liquid quarts (qt.)	Liters (l)	U. S. gallons (gal.)	Liters (l)
0. 27052=1 . 54104=2 . 81155=3 1. 08207=4 1. 35259=5 1. 62311=6 1. 89363=7 2. 16414=8 2. 43466=9		0. 033815=1 . 067629=2 . 101444=3 . 135259=4 . 169074=5 . 202888=6 . 236703=7 . 270518=8 . 304333=9		1=0. 47317 2= . 94633 3=1. 41950 4=1. 89267 5=2. 36583 6=2. 83900 7=3. 31217 8=3. 78533 9=4. 25850		1=0. 94633 2=1. 89267 3=2. 83900 4=3. 78533 5=4. 73167 6=5. 67800 7=6. 62433 8=7. 57066 9=8. 51700		0. 26418=1 . 52836=2 . 79253=3 1. 05671=4 1. 32089=5 1. 58507=6 1. 84924=7 2. 11342=8 2. 37760=9	
1= 3. 6966 2= 7. 3932 3=11. 0898 4=14. 7865 5=18. 4831 6=22. 1797 7=25. 8763 8=29. 5729 9=33. 2695		1= 29. 573 2= 59. 146 3= 88. 719 4=118. 292 5=147. 865 6=177. 437 7=207. 010 8=236. 583 9=266. 156		2. 1134=1 4. 2268=2 6. 3403=3 8. 4537=4 10. 5671=5 12. 6805=6 14. 7939=7 16. 9074=8 19. 0208=9		1. 05671=1 2. 11342=2 3. 17013=3 4. 22684=4 5. 28355=5 6. 34026=9 7. 39697=7 8. 45368=8 9. 51039=9		1= 3. 78533 2= 7. 57066 3=11. 35600 4=15. 14133 5=18. 92666 6=22. 71199 7=26. 49733 8=30. 28266 9=34. 06799	

5. CAPACITY—DRY MEASURE

U. S. dry quarts (qt.)	Liters (l)	U. S. pecks (pk.)	Liters (l)	U. S. pecks (pk.)	Deka- liters (dkl)	U. S. bushels (bu.)	Hecto- liters (hl)	U. S. bushels per acre	Hecto- liters per hectare
0. 9081=1 1. 8162=2 2. 7243=3 3. 6324=4 4. 5405=5 5. 4486=6 6. 3567=7 7. 2648=8 8. 1729=9		0. 11351=1 . 22703=2 . 34054=3 . 45405=4 . 56756=5 . 68108=6 . 79459=7 . 90810=8 1. 02161=9		1=0. 8810 2=1. 7619 3=2. 6429 4=3. 5238 5=4. 4048 6=5. 2857 7=6. 1667 8=7. 0477 9=7. 9286		1=0. 35238 2= . 70477 3=1. 05715 4=1. 40953 5=1. 76192 6=2. 11430 7=2. 46668 8=2. 81907 9=3. 17145		1=0. 8708 2=1. 7415 3=2. 6123 4=3. 4830 5=4. 3538 6=5. 2245 7=6. 0953 8=6. 9660 9=7. 8368	
1=1. 1012 2=2. 2024 3=3. 3036 4=4. 4048 5=5. 5060 6=6. 6072 7=7. 7084 8=8. 8096 9=9. 9108		1= 8. 810 2=17. 619 3=26. 429 4=35. 238 5=44. 048 6=52. 857 7=61. 667 8=70. 477 9=79. 286		1. 1351=1 2. 2703=2 3. 4054=3 4. 5405=4 5. 6756=5 6. 8108=6 7. 9459=7 9. 0810=8 10. 2161=9		2. 8378=1 5. 6756=2 8. 5135=3 11. 3513=4 14. 1891=5 17. 0269=6 19. 8647=7 22. 7026=8 25. 5404=9		1. 1484=1 2. 2969=2 3. 4453=3 4. 5937=4 5. 7421=5 6. 8906=6 8. 0390=7 9. 1874=8 10. 3359=9	

6. MASS

Grains	Grams	Apothe- caries' drams	Grams	Troy ounces	Grams	Avoird- pois ounces	Grams	Avoird- pois pounds	Kilo- grams
(gr.)	(g)	(dr. ap. or ʒ)	(g)	(oz. t.)	(g)	(oz. av.)	(g)	(lb. av.)	(kg)
1=0. 064799		0. 25721=1		0. 032151=1		0. 035274=1			1=0. 45359
2= . 129598		. 51441=2		. 064301=2		. 070548=2			2= . 90718
3= . 194397		. 77162=3		. 096452=3		. 105822=3			3=1. 36078
4= . 259196		1. 02882=4		. 128603=4		. 141096=4			4=1. 81437
5= . 323995		1. 28603=5		. 160754=5		. 176370=5			5=2. 26796
6= . 388794		1. 54324=6		. 192904=6		. 211644=6			6=2. 72155
7= . 453592		1. 80044=7		. 225055=7		. 246918=7			7=3. 17515
8= . 518391		2. 05765=8		. 257206=8		. 282192=8			8=3. 62874
9= . 583190		2. 31485=9		. 289357=9		. 317466=9			9=4. 08233
15. 4324=1		1= 3. 8879		1= 31. 103		1= 28. 350		2. 20462=1	
30. 8647=2		2= 7. 7759		2= 62. 207		2= 56. 699		4. 40924=2	
46. 2971=3		3=11. 6638		3= 93. 310		3= 85. 049		6. 61387=3	
61. 7204=4		4=15. 5517		4=124. 414		4=113. 398		8. 81849=4	
77. 1618=5		5=19. 4397		5=155. 517		5=141. 748		11. 02311=5	
92. 5941=6		6=23. 3276		6=186. 621		6=170. 097		13. 22773=6	
108. 0265=7		7=27. 2155		7=217. 724		7=198. 447		15. 43236=7	
123. 4589=8		8=31. 1035		8=248. 828		8=226. 796		17. 63698=8	
138. 8912=9		9=34. 9914		9=279. 931		9=255. 146		19. 84160=9	

VIII. OFFICIAL ABBREVIATIONS OF INTERNATIONAL METRIC UNITS

These abbreviations are used by the Bureau of Standards conformably to the principle followed in the abbreviations adopted by the International Committee on Weights and Measures, October 2, 1879. (*Procès-Verbaux des Séances de 1879, Comité International des Poids et Mesures; vol. IV, p. 41; 1880.*)

Metric abbreviations are simply the initial letters of the respective units combined with the initial letters of the prefixes set solid in lower case, and without period.

PREFIXES		UNITS
k	kilo-	m meter
h	hecto	g gram
dk*	deka-	l liter
d	deci-	a are
c	centi-	
m	milli-	

LINEAR (length)	SQUARE (area)	CUBIC (volume)
km kilometer	km ² square kilometer	km ³ cubic kilometer
hm hectometer	hm ² square hectometer	hm ³ cubic hectometer
dkm dekameter	dkm ² square dekameter	dkm ³ cubic dekameter
m meter	m ² square meter	m ³ cubic meter
dm decimeter	dm ² square decimeter	dm ³ cubic decimeter
cm centimeter	cm ² square centimeter	cm ³ cubic centimeter
mm millimeter	mm ² square millimeter	mm ³ cubic millimeter
μ micron (=0.001 mm)	μ ² square micron	μ ³ cubic micron

MASS** (weight)	SURFACE (land area)	CAPACITY (of containers)
kg kilogram		kl kiloliter
hg hectogram	ha hectar	hl hectoliter
dkg dekagram		dkl dekaliter
g gram	a are	l liter
dg decigram		dl deciliter
cg centigram	ca centare	cl centiliter
mg milligram		ml milliliter

NOTE.—A similar plan is used for abbreviations of cgs units and others: mf millifarad (m milli, f farad); μf microfarad; mμ a thousandth of a micron, and μμ one millionth of a micron. (See Guillaume: *Unités et Étalons*, p. 7, note.)

* "dk" suggested and used by bureau to distinguish from "d."

** "t" = 1,000 kg = metric ton.



