The First Canadian Work of the Twentieth Century

Decimals and Decimalisation

A STUDY AND SKETCH

BY

Arthur Harvey

ACTUARY, F.R.S.C., ETC.
TORONTO, CANADA

Price - - - - 15 Cents

TORONTO
THE HUNTER, ROSE CO., LIMITED
1901

WHOLESALE AGENTS—THE MUSSON BOOK CO.

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Decimals and Decimalisation

Introduction

"Let me see," says the clown in Shakespeare's "The Winter's Tale." "Let "me see:—every 'leven wether tods; every tod yields— "pound and odd shilling; fifteen hundred shorn, what "comes the wool to?" Then, after a pause, he adds: "I "cannot do't without counters." The sum is not a hard one now-a-days. Eleven sheep give a tod (i.e. 28 lbs.) of wool, worth £1. 1s. 0d., what will fifteen hundred yield? Evidently £1500, plus 1500s., or £75; together £1575, divided by eleven, which, in 33 figures, gives £143 3s. 7½d. In this country it would be still more simply solved. Eleven sheep produce wool worth $5.11, so the answer comes at once, $5.11 × 1500 ÷ 11 = $696.82, which needs no reduction.

The young man, though "a plain fellow," and easily cozened by Autolycus, had a fair education, of a rustic kind. Indeed the implication is evident, that he could do the sum with counters, which few, if any, of us could manage. Thus, on reflection, we shall see that in these few simple words we are brought close to one of the chief reforms of recent times, viz.: the use in arithmetic, not merely of decimals, but even of the figures we now employ. They may serve then as a fitting text for a disquisition, in which, after a brief glance at the history of decimal notation, and at what has been already accomplished in lightening the world's mental labour by decimalising, in many countries, coinage, weights and measures, instances of incomplete decimalisation will be alluded to, and a reason given for the hope that we shall soon see the reform enlarging its scope and freeing us more and more from the wretched trammels of ancient servitudes.

Early Systems of Numeration

The earliest system of numbers was doubtless based on halves and doubles, and there are many native tribes in America whose numerals only extend to four. Some savages, indeed, like many of the Australian aborigines, have not yet got to that, and express more than three by a noun signifying multitude. Most tribes, however, soon progressed so far as to count five, being the number of the fingers of the hand, whence it was not difficult to reach the conception of ten. In Homer's Odyssey (8. 411-414) the old sea-god Proteus is spoken of as counting his herd of seals by fives, before going to rest among them, but Aristotle, a few hundred years later, says that in his time almost all nations, civilized or barbarous, used a decimal-system, except the Thrakians, who only counted to four, and said they could not remember any further quantity.

The earliest records of the Egyptians show that they had a decimal system, and there we seem to find the origin of the figures now used as signs of numbers. The Chinese have had for thousands of years a very complete decimal system, and use with great rapidity and accuracy an abacus based on fives and tens—a refinement, possibly, on our friend the clown's counters.

Introduction of Decimal Reckoning

Our decimal system came to us from India, (possibly by way of Bactria) through Arabia; supplanting Roman methods and numerals. The principal stages in this westward march of progress are thus marked:—Aryabhata wrote in Sanscrit on algebra and arithmetic in the fifth century. Mohammed Ben Musa made these Hindoo sciences known to his Arabian countrymen in the ninth, and they came into general use throughout Arabia in the tenth century. In the eleventh, the Moors and Arabs had established themselves in Spain, whither they carried their decimals with their victorious arms. And in the twelfth century this new method of notation spread into Italy, and so into the rest of Europe. It is curious how the old notation clings on here and there; you will find it on the title-pages and in the preface-pagination of many books, on tombs and tablets which bear commemorative inscriptions, on most of our clocks and watches. It is still more curious to reflect how recent is the introduction of the present method of writing numbers. Chaucer, who died in 1400, alludes to it as a novelty. In his "dream" he sees so many wonders that even Argus could not number them, though he

> "Ysate to rekin in his comtour,
> "And rekin with his figures ten;
> "For by the figures newe, al ken—
> "If they be crafty—rekin and number and tell
> of everything the nomber."

If particular credit is to be given to one of the many mathematicians and publicists who from that time forward gave their enthusiastic support to the decimal notation, we must select Simon Stèvin, or Stevinus, born at Bruges, Belgium, whom we may call the Dutch Leonardo. He was, *inter alia*, director of fortifications for the Prince of Orange, hydraulic engineer in charge of river improvements and canals, and the author of a work upon decimals called "De tiende," issued in 1585, at Gouda. It was translated into English in 1608, by one Norton, under the title "Disme, the art of tenths, or decimal arith-"metic, teaching how to perform all computations whatever "by whole numbers, without fractions." But that title is by no means explanatory of all Stèvin's views. He proposed the decimalisation of weights and measures, but as he was two centuries in advance of the most progressive people in the world, his idea had to undergo a long period of development, and is not yet fully carried into effect.

It is happily needless now to say more about decimal numeration, for its use—much aided in England two hundred years ago by one Mr. Cocker, whose arithmetic reached nearly forty editions, and gave rise to the familiar proverb, "that's not according to Cocker"—is now co-extensive with civilization, though school children still suffer from the antiquated methods of reckoning, being over-much troubled with the fractions once in common use, and therefore called "vulgar." Such survivals are often long-enduring. Arabic figures were not adopted in the public accounting of England until 1831.

Duodecimal and Sexagesimal Systems

In passing to the consideration of coinage, weights and measures, we clash at once with the remains of another system, the duodecimal. The writer, indeed, thinks that in the method of weighing diamonds we have a relic of a still older civilization. In this, the carat is the unit, though not everywhere of the same weight. It is divided into halves, fourths, etc., down to sixty fourths, though the method of weighing by carats and decimals of a carat is now frequently used in America and Canada. So, too, the mode of weighing pearls is of immemorial antiquity, the grain being the unit, divided into fourths only. But the duodecimal system, if later, is prehistoric too. It was possibly prevalent among the Mongoloids, who once occupied Europe, for it clings to many places there with all the tenacity of a survival. In the dawn of history we find it in full use among the Mongolians of the lower reaches of the Tigris and the Euphrates, where the Paradise of the Hebrew book of Genesis has usually been placed. They were a numerous and industrious folk, largely agricultural, and therefore much interested in astronomy and cognate sciences. Great quantities of tablets have been found at Nineveh, with inscriptions in cuneiform characters but in the Akkadian language, which persisted long after the Semitic people, who broke in as conquerors, had become imbued with the civilization they found existent. To this Accad or Akkad-Chaldaean race, certainly Turanian, we owe the division of the day into two parts of twelve hours each, of the hour into sixty minutes, and of the minute into sixty seconds. These divisions follow from the division of the circumference of the heavens into the twelve Zodiacal signs, and of the circle into three hundred and sixty degrees, each sub-divided into minutes and seconds, like the hour. It seems that these Akkadians, aided by the Zodiacal signs, took certain stars as reference marks, and as each star came up, it divided the night into six parts of two hours each, which, being long for practical purposes, were cut in twain, and thus, at least four or five thousand, but probably twice as many years ago, our present division of time originated. In Babylon, the standards of length, capacity and weight were divided, like the hour, into sixty parts, these again into sixty, and so on. This method was imposed on Egypt too, at an intermediate period, but does not seem to have met with universal favor, the latest dynasties returning to a decimal plan, like the oldest. The Roman system, which still influences ours, was originally duodecimal too, the coinage being based upon the copper As of twelve ounces. But, not to delve too deeply into history, we may note that, to this day, twelve inches make one foot, three feet one yard, and six feet one fathom. We reckon twelve ounces to the pound Troy, twenty-four grains to the pennyweight. We count twelve pence to the shilling, and sell many articles by the dozen. We write on paper which has 24 sheets to the quire, with pens which we buy by the gross of a dozen dozen, which is a full twelve months' supply.

The decimal base is doubtless in some respects inferior to others; you cannot divide ten by either three or four without a remainder. As it is often convenient to halve a half, eight would be in some ways better than ten, and twelve would seem to be scientifically the best. Yet the duodecimal has everywhere and at all times yielded before the decimal system, and, now that intercommunication has become so rapid, intercourse and exchanges so frequent, that the civilized world is like one family, we ought to abolish all needless divergencies as soon as possible.

Origin of the Metric System

This idea took strong hold of the French people at the end of the last century, when they were changing many other things besides weights and measures, and in 1790 the celebrated Talleyrand carried a resolution in their Assembly which looked to the adoption of a scientific standard by all nations, with a view to the introduction of a uniform coinage, and of international weights and measures. It read: "That a commission be formed, "charged with the duty of ascertaining the length of the "pendulum beating seconds in latitude 45°." England, though invited, refused to join the commission, so the French and dependent nations proceeded alone. They soon threw over the pendulum standard, for the commission advised taking in its stead a fraction of the earth's meridian. This involved the determination of the length of the degree, a subject which has an interesting history.

Measuring this Earth

It begins with Eratosthenes (250 years B.C.), who observed that at Syene, in Egypt, at the summer solstice, there was no shadow at mid-day at the bottom of the wells, whereas at Alexandria, at that time, a rod set vertically did throw a shadow, which he measured. His calculations showing that between these two places there was one-fiftieth of the circumference of the sphere, and the distance being 5,000 stadia, it followed that the earth's circumference was 250,000 stadia, which is about 1,800 of our standard miles too much. Poseidonius made another measurement, on the same principle, between Alexandria and Rhodes, and brought out 5,580 geographical miles as his result, which is only about 800 miles in excess of the truth. Very little more light was thrown upon the subject for a millennium, but in A.D. 1525 a new method of computation was resorted to by Fernet, who measured the distance between Paris and Amiens by the rotations of his carriage wheel, observed the solstitial altitude of the sun at each place and brought out an estimate of the length of a degree surprisingly accurate, considering the imperfection of his astrolabe or whatever other goniometer he used. In 1615 one Snell, or Snellius, a Dutchman, invented the system of triangulation, and in 1666 Picard measured by this means the length of an arc of one degree, between Amiens and Malvoisine, thinking he had thus arrived at an absolutely correct measurement of the circumference, and therefore of the diameter of our world.

Shape of the Earth

But then came Newton, with his law of gravitation, explaining that by reason of centrifugal force the figure of the earth could not be spherical, but must be flattened at the poles—a hypothesis confirmed by Huyghens in theory and by Richer through pendulum observations at Cayenne, which is less than 10° north of the equator. The French Academy, which had taken issue with Newton, then prevailed on the Government to measure an arc in Peru, to compare with another, measured by Swanberg, in Lapland, and the result, that a degree in Lapland is longer than one in Peru, gave Newton's theory a notable triumph. Cassini's great name is connected with this celebrated calculation. The triangulation in Peru was made under Bouguer, between 1746 and 1753, and its comparison with the Lapland arc has ever since given us the astronomical and geometrical standards, thus being the basis of the principal constants in the mathematics of the solar system.

If (a) be the semi-axis major of an ellipse, and (b) the semi-axis minor, the flattening is defined by $x = \frac{a-b}{a}$. The Quito or Peruvian observations, combined with Swanberg's, gave a compression of $\frac{1}{309.4}$, but a revision gave $\frac{1}{329.25}$. Then came some measurements in France made by Delambre and Mechain, who calculated on the basis of an arc between Paris and Barcelona, and compared it with the Peruvian and Lapland arcs, and brought out as a result $\frac{1}{329.04}$. Laplace, from the lunar motions, made the compression $\frac{1}{314}$. From the theory of gravity, combined with observations by Burg and Maskelyne, $\frac{1}{309.05}$ results. Dr. Robison, assuming the variation of gravity at $\frac{1}{190}$, makes the compression $\frac{1}{319}$. The computation from the precession of the equinoxes, and the nutations of the earth's axis, gives $\frac{1}{304}$ as the maximum limit. But since the date of these calculations Europe has been further triangulated, arcs having been measured in Hanover, Sweden, and elsewhere. England is connected with France, and France, through Spain, with Algiers. The figures denoting the flattening have been successively changed to $\frac{1}{308}$, to $\frac{1}{299}$ which is Bessel's, to $\frac{1}{292}$ which is Fayes'. Clarke, the Englishman, made it $\frac{1}{293.46}$, which is adopted in England and France as the astronomical constant, while other countries generally follow Bessel *

Another element has lately been introduced into the problem. Tisserand has satisfied the Academy that the English contention of a hundred years ago is true, and that the various meridians do not all belong to the same ellipsoid of revolution; in other words, it is not yet clear that the various ellipses have the same centre, or that the earth has a regular figure. Hence the formation of an international geodetic union, and the determination not only to remeasure the Peruvian arc, but to extend it from $3\frac{1}{2}°$ to 5° or 6°. The French, who have the historic right to undertake the delicate task, have not shrunk from its responsibilities. International boundaries in South America have meantime changed, the arc is principally in Ecuador, the northern part being in Colombia, and only the southern end in Peru. It is to be hoped that the republics will be reasonably tranquil during the operations of the expedition, whose headquarters are at Quito, only 14′ south of the equator, and which expects to finish its work within four years. The Russians and Swedes are meantime completing the measurement of a northern arc in Spitzbergen. We shall also have extensive arcs in South Africa, India, and on the 98th meridian from Mexico to the farthest north, all of which will be exceedingly useful for purposes of comparison.

The strictly logical mind of the French demanded some such standard of length; also that it should be brought into relationship with standards of capacity and weight,

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*See a paper by Dr. H. S. Pritchett, of the U.S. Coast Survey, in the Transactions of the Royal Society of Canada for 1898.

though there is no practical reason why a fraction of the earth's circumference should be a better norma than any other length, determined with reference to convenience. When the new measurement of the mean degree is completed it does not follow that the present French standard measures will or should be changed, but it is possible they will be, and it is to be hoped that a determined effort will then be made, all over the world, to complete the decimalisation of weights and measures, also of coinage, and their unification as far as practicable.

Inconvenience of British Coinage

One of the Canadian contingent in South Africa, used to dollars and cents, was called upon to act as regimental paymaster, and wrote in dolorous tones of the waste of time in making up the pay roll in £. s. d., twelve pence to the shilling and twenty shillings to the pound. We, who are habituated to a decimal currency, can picture him to ourselves, worrying over hundreds of entries, in three columns, with many compound multiplications, additions and subtractions, all in a queer and antiquated currency, and can fancy him sympathizing with Dickens' Mantalini, who wished to skip the intermediate steps and arrive at once at the "demnition total."

Sir John Bowring, in his work on the decimal system, devotes some pages to exemplify the difference between the figures required for calculations with and without decimals. One account of 215 tons, 17 cwt., 3 qrs, 9 lbs., at £9. 11s. 6½d. a ton, takes 208 figures to make up in the usual way, whereas if stated decimally it would require but 66. Prof. De Morgan asks, "how much in the pound is £43. 17s. 4¾d.?" and takes 42 figures to work it out, whereas, with a decimal coinage, the question would be answered by the figures themselves. In going through a number of calculations of common occurrence, using first English money and non-decimalised weights and measures, and then decimalised coinage and standards, the writer has found a saving of one-half in the number of figures, and of one-half more in the time needed for processes of mental conversion, such as from ounces to pounds and pence to shillings and pounds sterling.* A curious instance of the complications still forced upon us here, is shown in the practice of assayers when asked for the quantity of gold and silver per ton of ore. They have to make an arbitrary or proportional weight of 29.166 grammes (metric) which they call an assay ton. Then, every milligram of precious metal they find in that weight of ore is the equivalent of a troy ounce in an avoirdupois ton of 2,000 lbs. They use metric weights in their balances, but have to make the return in ounces, pennyweights and grains Troy—24 grains to a pennyweight and twenty pennyweights to the ounce. That suffices for America, but if the result has to be forwarded to England, there must be further reductions to the long ton of 2,240 lbs., and to £. s. d.

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* The English actuary often finds it convenient to use tables which show the decimal parts of a pound corresponding to any number of shillings, etc., also the decimal parts of a year corresponding to any number of days.

Decimal Coinage of the U.S. The United States had little difficulty in adopting a decimal coinage. In 1790 Mr. Jefferson, then Secretary of State, said: "The experiment made by Congress in 1786, by "declaring that there should be one currency of accounts "and payment throughout the United States, and that its "parts and multiples should be in a decimal ratio, has "obtained such general approbation . . . that nothing "seems wanting but the actual coinage to banish the dis-"cordant pounds, shillings, pence and farthings of the "different States, and to establish in their stead the new "denominations." Mr. Quincy Adams particularized this discordance when he wrote: "At the close of the war for "Independence, we found ourselves with four English "words—pound, shilling, penny and farthing. . . . But, "though English words, they were not English things. "They were nowhere sterling, and scarcely in any two "States of the Union were they representatives of the "same sums. . . . We took the Spanish piece of eight, "which had always been the coin most current among us, "and to which we had given a name of our own—a dollar. "Introducing the principle of decimal division, we said, "a tenth part of our dollar shall be called a dime, a hun-"dredth part a cent, and a thousandth part a mille." For all this, it took more than a generation to have the nomenclature and the coinage generally adopted. The dollar was long popularly reckoned as ninety pence, the English shilling was used as an eleven-penny bit, the sixpence was fivepence in Philadelphia, fourpence halfpenny at Richmond, sixpence in New York city. In Canada it is still spoken of as a York shilling.

The British-American colonies long preserved their £. s. d. In those which now form the Dominion of Canada, Halifax currency was used, in which £111. 2s. $2\frac{2}{3}$d. equalled £100 stg. Laws were enacted in the separate Provinces to arrange a fair equivalent in British and in American coin for this paper value, but they were not alike, and the dollars and cents of the American republic won their way so rapidly in private counting houses, that no shock was felt when the public accounts of Canada were converted into that currency, just before Confederation, and a Dominion Statute sanctioned the change. Silver and copper coins have been minted for the Government, in England, but it is now proposed to establish a mint of our own, in which not only dollars and their multiples and parts are to be struck, but also British sovereigns. These could, however, only be used here in the adjustment of exchanges with Europe and in trade with China and Japan, for Canadians could never reintroduce to this continent the monetary confusion from which, by adopting the dollar, they have but lately escaped.

The monetary system of France was, in like manner, much confused before the new franc was introduced as the unit, at the Revolution. The French had livres, sols and deniers as means of account, but the coins were non-concordant. The écu or crown was perhaps the accepted standard, equal to six livres.

Proposed Changes in British Currency

On the other hand, the currency of Great Britain is stable, it is now uniform over the three kingdoms; the coinage is in accord with the system of accounts, and decimalisation has to be approached with much caution. The only unit possible there is the present pound sterling. A committee of the House of Commons in 1853 recorded their conviction that the pound sterling must be maintained, but thought the obstacles to its decimalisation were "not of such a nature "as to create any doubt of the expediency of introducing "that system." The committee advised that action should be "cautiously" taken by the government, but the writer is unaware of any action being taken at all, for the florin had been already coined. The florin (= two shillings or one-tenth of a pound) has not become popular, which goes to show that excessive caution defeats itself. An isolated coin like the florin, which has no place in account keeping, and no subsidiary decimal subdivisions, is useless for purposes of experiment; and one might say an enemy to decimalisation had posted this detachment on a kopje, without means of defence or offence, so that it must at the first summons surrender to the foe. The committee very justly added that action should be "decisive," which appears to onlookers to involve the legalisation of a decimal system of accounts, the issue of a complete series of decimalized coins, together with a fiscal measure looking to the redemption of the existing copper coinage, which does not fit in to any proper system, and the withdrawal of a few silver coins which are confusedly named.

To us, who have with ease glided into the use of decimal moneys, it seems that the people of Great Britain are unduly conservative, for the changes needed are very simple. Applying a nomenclature, merely by way of respectful suggestion, the table would be:

£1 = 10 florins
1 florin = 10 dismes
1 disme = 10 doits.

The doit or mil would be a trifle below the value of the present farthing, 1,000 going to the £1 instead of 960. Opponents of decimalisation for England say a farthing is a very important coin, but to us it seems too trifling to create concern in actual transactions over the counter, while as a value in account, the mil is rather more useful and very much easier to deal with. The English would certainly regret the penny, but even that name would probably be restored with a new value, as soon as the old coinage had gone out of circulation. The new coinage would require :

Value.	Name.	Multiple of the Mille.
£1.000,	the sovereign	1,000 mils.
.500,	the half sovereign	500 "
.100,	the florin	100 "
.050,	the shilling or semi-florin	50 "
.010,	the disme or tenner	10 "
.005,	the new penny	5 "
.001,*	the doit	1 "

In all seven pieces, three only being new. The first two would be of gold, the next three of silver, the last two of bronze. A short period of confusion would ensue, in respect of the lowest values, which give rise, it is true, to the most numerous transactions, but its endurance should be rendered easier by the conviction that the reform would

*The experience of countries which have adopted the decimal system in its completeness proves that it is desirable to have new names for new coins, weights and measures. This small point is really a most important one. Also "doit" is preferable to "mil" as avoiding confusion with American values.

benefit untold future generations. The greatest dislocation would be in the matter of penny postage and revenue stamps, and possibly these might for a time be retained in use. Their sale for the old currency of pennies and sixpenny pieces might be made to assist in taking such coins out of circulation. The appearance of £43.825 instead of £43. 16s. 8½d. would not long be strange. It will be observed that, owing to the larger value of the British unit, three places of decimals would be required instead of our two, but the number of figures needed would not therefore be materially increased.

Need for Britain to Adopt the Metric System

But whether Great Britain decimalises its coinage or not, the weights and measures of all exportable products and manufactures ought to be decimalised, and as England cannot compete without disadvantage in countries which have adopted the metric system, while they, after experiencing its value, would not abandon it, that would be the best to introduce. There would be no loss of dignity in so doing. England followed the Gregorian or Roman reform of the calendar without loss of national standing, and the convenience in the case of weights and measures would be greater than in the case of uniformity of dates. Russia, even yet reluctant to follow the Roman lead, in time, is preparing to adopt the metric system, and if Britain does not, it will be another case of splendid isolation. Quite possibly it is her not having joined her neighbours in commercial systems of this nature which has caused her to be regarded with so much dislike. The metre of 39.3707904 inches, or one ten-millionth of the earth's mean quadrant, will not be appreciably changed in consequence of the re-survey of the Peruvian arc. It is as convenient as the yard, and the kilogram is almost as suitable for a weight as the ton. There would be no need for a sudden change in non-exportable matters. Builders' measurements might still go by feet, which should, however, be divided into tenths, so that the inch would be lengthened, and preferably under another name. Acreage might remain as it is, but the rod would vanish and so would the yard. The acre is already decimally sub-divided by the surveyors' chain and its links—ten chains square being one acre, and the chain consisting of 100 links, while the steel tapes used for city surveys are even now marked on both sides by the best makers—metres on one and feet on the other. Local measures, such as toises of stone, might well be left to die a natural death. Even if the nation could not get so far as to adopt the metric standards of length and weight, and merely decimalised the foot and the pound, how convenient it would be to write 10.54 feet instead of 3 yards, 2 feet, 6½ inches, and 356.50 lbs. instead of 3 cwt., 20 lbs., 8 oz. avoirdupois. But such a partial reform ought not to content the peoples who claim to be the most intelligent and best schooled in the world.

Reports from British Representatives

Lord Salisbury was asked by the Associated Chambers of Commerce of the Empire to seek for information as to the mode in which the metric system was introduced into the various countries of Europe, also as to whether it is satisfactory in practical operation. The various embassies here sent in complete memoirs on the subject, and they were submitted to Parliament in July last. A summary of this important paper is given in an appendix. It shows that every country in Europe has adopted the metric system except Russia, Turkey and Denmark. The two former only refrain because of the low state of culture of their people, and the last because of its peculiar form of government, one chamber representing the peasants only, an electorate which these representatives fear to offend. Switzerland took but a year and a half to introduce the system; the time deemed requisite in others was in one case three, in others five or ten years, in some twenty or even more, but none of them would now revert to the old system, because the new one saves the time of the children at school and permits of their using it in other studies than that of complicated arithmetical calculations, because it saves time and risk of error in mercantile transactions, and because it facilitates internal and external trade. Several of the authors of these valuable reports say that England loses many orders for merchandise because foreign dealers are unwilling to translate their requirements into the barbarous measures of that country. Most European nations had a variety of local weights and measures, and the unification of the standards was on that account a highly appreciated boon: the same reason would to some extent serve to popularise the metric system in England, if it were made compulsory, for there are 108 different weighed measures by which the British farmer sells his cereals, while he measures his land by something like 40 different acres.* There is, too, amongst chambers of commerce a very general opinion that the metric system

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* Bibby's Quarterly, summer number, 1900, page 105.

should be thus compulsorily adopted.* If, in Parliament, the leaders of both political parties would agree to pass a law, with practical unanimity, it could be safely made compulsory in one year from its date. All the colonies would at once follow suit. The use of metric measures in accounts seems to be legal in England already, but traders are prohibited from using them on their counters—a worse form of trial than that mentioned in the case of the poor florin! If the introduction of the new standards were determined upon, it would be advisable for each school to have a set, and for every scholar to know how to use them and how to compare them with the present standards. Frequent examples should be worked out, to show the practical simplicity of the system. The cost of the introduction may be calculated at something less than ten cents per head of the population. Some less classical names may be substituted for those current in Europe, if desired. The lesson to be learned from the reports is that the system should be dealt with as a whole, and made compulsory at a given future date, prior to which the schools should be utilized for making known the principles of the reform, and for demonstrating the practical ease and utility of the change. Popular interest and even enthusiasm is then excited in its favor, and the inconveniences incidental to the change are cheerfully borne.

In Canada the metric system is already legalized, but it is not progressing. Indeed, the Dominion cannot move in the matter effectively until at least one of its chief customers does so, for its trade is so largely carried on with

* Letter to the Marquess of Salisbury from Edw. W. Fithian, Sec'y Associated Chambers of Commerce, Nov. 2nd, 1899.

England and the United States that it would be hindering the bulk of its foreign commerce if it made the metric system compulsory before either of its chief customers had seen fit to do so.

The Metric System in the U.S. Congress

But the United States is already moving. A committee of the House of Representatives on coinage, weights and measures has given its unanimous endorsement to the adoption of the metric system as the legal standard of the United States, on and after January 1st, 1903, and the chairman of the committee was authorised to report the measure to the House on the first opportunity. The bill in its present form is hardly likely to become law, but the U.S. inspector of weights and measures, Mr. S. W. Stratton, has been so good as to inform the writer, through the Bureau of American Republics (one of whose objects is the unification of weights and measures all over America), that "this endorsement by the committee will certainly give impetus to the movement, which we confidently believe will ultimately result in the exclusive use of the metric system in this country." In Cuba, Porto Rico and the Philippine Islands the metric system is in general use, and in all customs transactions there it is used by order of the military authorities.

Scientific Scales

Such reforms seldom get much help from professionally scientific men; the common sense of fairly educated people is more to be relied on for their advancement. Who would have supposed, for instance, that the thermometric scale would differ in different countries? We use the Fahrenheit scale, but the centigrade ought at once to supplant both that and Rhéaumur's. Newton, in 1701, prepared a scale in which the freezing point of water was called zero, and the heat of the human body 12 degrees. Celsius is really the father of the centigrade scale, for he proposed in 1742 that the boiling point be zero and the freezing point 100. Rhéaumur divided this into 80 instead of 100 parts. Fahrenheit assumed as an empirical zero the lowest temperature up to his time recorded, and marked the heat of the body eight divisions higher, each of which he sub-divided into twelve degrees, so that blood heat was called 96°. It was found that by this scale water froze at 32° and boiled at 212°. These points then became fixed, and although the assumed blood heat has been found to be inaccurate (it is really 98°), and we have recorded temperatures very far below zero, the Fahrenheit scale is still in common use in England and English-speaking America. The centigrade scale takes as its zero the freezing point of water at sea-level, when the barometer measures 29.92 inches (or 760 millimetres). Its 100° is the boiling point under similar conditions. It is in use in France, Italy, Spain, and other countries.* The centigrade scale does not call for improvement, though a Congress, to consider of its general

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*Only a few weeks ago I was reading Dr. Sven Hedin's recent travels near the Lob Nor, in Central Asia. He left that marsh when the thermo. was 42 degrees above zero, Celsius, though in winter it had been known to fall to 32 degrees below. The translator was perhaps unable, and I was too lazy to convert this into Fahrenheit, so the figures convey no precise meaning.

adoption, might discuss the possible advantage of placing the zero just 100° lower, so as to avoid the confusion of frequently using the sign - (minus). If, however, the boiling point were marked 200, there would be inconvenience from using three figures for ordinary temperatures, and the decimalisation of the scale would be less complete.

If a Congress should be called, the chemists and physicists would have a number of standards to argue about, e.g., the proper standard for atomic weights. If hydrogen be 1, oxygen is not exactly 16, so why oxygen should be taken for the standard at exactly sixteen, which throws hydrogen slightly above 1, is not easily comprehensible. The minority which prefers either hydrogen at 1 or oxygen at 100 is still loudly protesting.

Decimalisation of the Arc

We now approach another more important and more difficult subject, the subdivision of the circumference of the circle. Our present method of dividing it into 360 degrees is the oldest relic of prehistoric science we possess. Mr. Flinders Petrie has lately proved by excavations among the tombs of the first Egyptian dynasty, near Abydos, that already in 4,600 B.C. the year consisted of 365 days, and the need for a leap-year was known, so that the path of the sun among the stars was understood, and the heavens were divided into Zodiacal spaces, as among the Chaldaeans. Our present constellations are thought to be of somewhat later origin.* The division of the

*See a paper by Mr. Maunder in the *Nineteenth Century* for September, 1900.

degree into sixtieths remained unquestioned until the time when logarithms came in. Parenthetically one may note that Napier of Merchistoun, the inventor of logarithms, did not use ten as his base, but calculated his tables in what are called natural logarithms. He, however, advised his friend Briggs to calculate and publish tables according to the decimal base, and not only was this done, as to numbers, but, in addition, Briggs calculated, although he left unfinished, a table completed and published in 1633, in which he did not interfere with the ninety degrees of the quadrant, but subdivided each degree into hundredths. Several calculators on the continent followed him, the latest of whom, prior to the decimal revolution, was Schulze, of Berlin. Lagrange at first supported this method, but, later, he became a partisan of the method of dividing the quadrant into a hundred grades. Schulze then recalculated his tables, and between 1794 and 1809 numerous publications based on this principle were made both in Germany and France. In their measurement of the Peruvian arc Delambre and Mechain used theodolites with their *cercles repetiteurs* divided into 400 grades. In 1818 the decimal division of the quadrant became obligatory on the officers of the Trigonometrical Survey of France, and has remained so. It is used, too, in the Geographical Service of the French War Office, in the Cartographical Institute of Belgium, in Wurtemberg and Baden. In 1883 the international Geodetic Society, meeting in Rome, passed a resolution in its favor, which has, however, not been generally acted on. For many contentions have arisen, whether the whole circumference ought not to be the unit, whether the circumference should not be divided into 240 instead of 360 parts, and whether the degree alone should not be decimalised.* Finally, in 1897, the French Government appointed a commission to study the conditions of the problem, involving, as it did, questions of time and arc both. To aid in the solution they appointed nine navigating officers of naval vessels to report on the advantages, or the reverse, of using decimals applied to the circle, giving them nine months to work in. These officers were supplied with instruments decimally graded and with appropriate logarithmic tables, and they have reported unanimously that the substitution of a new unit can be made without difficulty, since the calculators and observers adapted themselves to its use at once. They all said calculations by the new method were easier and less liable to error, and most of them advised the immediate adoption of the reform. The table would be

1 Quadrant = 100 grades.
1 Grade = 100 centigrades,

with decimals for millegrades, etc.

Decimal Division of Time

The question of time divisions, which are immediately connected with those of the arc, presents yet greater difficulties. We must not think of the quadrant of 100 grades as applying to latitude only, for if it be 100° from the equator to the pole, it must be 400° around the equator, when the

*Mr. H. de Sarrauton, of Oran, Algiers, has lately published a table of logarithmic values of the arcs of the quadrant divided into sixty instead of ninety degrees—a work in which he was assisted by Mr. Vermont, of Bucharest.

usual correspondence between longitude and the hour would be well-nigh lost. Instead of 15° to the hour, we should have the repeating decimal 16°. 6·, and the adjustment of time notation to the new decimals of arc would become difficult. Here M. Lœwy, the director of the observatory at Mendon, Paris, calls a halt. "If," says he, "it were only a question of the intrinsic worth of the two "systems—if one could leave out of consideration old cus- "toms, instruments and tables in use, all competent men "would agree in favor of the proposed change. . . . But," he proceeds, "the project of bringing into use decimal "divisions of time does not seem to have the slightest "chance of success." Let us briefly examine the subject. If we took the day as the unit, there would have to be 40 divisions, to correspond with the four quadrants of 10 divisions each. Such figures would encumber the dials of the largest clocks and watches. If we took the quarter of the day for the unit of admeasurement, there would be room for the ten hours to be marked, but it might confuse us to have the hour hand going round four times in one day, and there would either be a violent dislocation of our oldest habits, or a fractional time reckoning in all our common affairs. If we took half the day and divided it into ten the new divisions would be very different from the old ones.

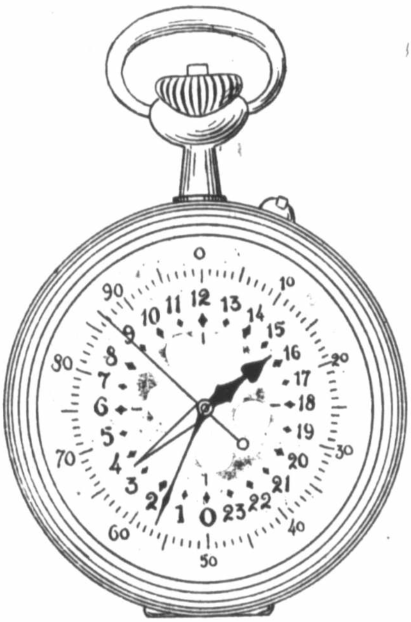
1 new hour = 1 old hour and 12 old minutes, or 1.2 of the old hour.
1 new tenth = 7.2 of the old minute.
1 new hundredth = 43.2 of the old second.

So there would have to be at least one other decimal division, which would mean four hands on one dial, or four dials to one watch. As the new hour would be so long, many more fractions of an hour would have to be used in settling times of labor and of refreshment, bells would have to ring at broken periods, and it would be long before such things were readjusted.

It is curious to reflect that the regularity of the hour is quite a modern convenience. Until very recently there were hours of different lengths, all over Europe, especially for summer and winter, and for day and night. In the Zend Avesta it is ordered that the day be divided into five periods—from midnight to sun-up, thence to mid day, to sunset, to the appearance of the stars, and so on to midnight—and the old Persians devoted those periods to sleep, sacrifice, work (a double portion), and prayer. The Egyptians used a somewhat similar series, but divided the time from sunrise to sunset into twelve parts, which made their summer hours longer than the winter ones. I understand that the Chinese observe the meridian transits of given stars by the eye only, not as we now do, with telescopes, and having tables, regulate their time, but that their hours are different by night and by day, and not of uniform length in either. We have become used to uniform hours since clocks became common; we find the convenience of the system, and shall not readily disturb the happy combination of ancient science and recent horological skill which now exists. If time and the arc have to be brought into accord, we shall more readily divide the arc into 240 degrees than change the hour. Mr. Lœwy is unquestionably in the right so far as this goes, and the writer thinks we should be satisfied to decimalise the degree and the hour, not the quadrant or the day. As the decimal notation in arithmetic was much aided by a simple expedient, the use of the zero, so perhaps the simple change in the 24-hour watch-dial suggested by M. de Sarrauton, of Oran, Algeria, may reconcile to that time-marking many recalcitrants. He puts a zero *at the bottom of the dial*, and marks the 24 hours all around. The hour-hand has a skeleton prolongation across the centre, which marks the hours of the common notation in the afternoon. Outside the hour circle the rim is divided into hundredths, and the ordinary minute hand marks out these shorter minutes. A third hand marks each hundredth of these short minutes in two beats, which gives a more accurate reading than the existing dial, quite as easy to comprehend. The reading would be h9.50 instead of 9h. 30m. (a.m.) and h21.75 instead of 9h. 45m. (p.m.). It does seem curious to stop at 60 minutes, and thus lose the advantage of continuity of system.

Summing up this question of subdividing the arc and the day, the writer thinks the circumference should be divided into 240 instead of 360 degrees, so that the hour would correspond to ten instead of fifteen degrees, and that the new degree and the old hour should be decimalised. That would not alter the standard time-belts, of an hour, difference between each, which are now coming into use all over the globe, or the 24-hour notation now used on our greatest railways, and adopted from the first of January last by the French Bureau of Longitudes. Nor would it interfere with the unification of the various kinds of day still used, or with the ultimate adoption of Cosmic time reckoning, to which the Canadian Institute has always given its approval, since its proposition by Sir Sandford Fleming. He also ventures to think that if some firm would manufacture a watch having a 24-hour dial, decimally divided on M. de Sarrauton's plan, it could scarcely fail to be a profitable venture, for it would be an ideal time indicator for astronomers, geographers, mariners, physicians, engineers, and at the same time serve to indicate the present divisions of the day and hour sufficiently for common purposes, pending the general adoption of decimal time notation.

To illustrate the beautiful harmony between the newly proposed division of the arc and of time, the writer has prepared from M. de Sarrauton's designs a model of the new dial. Placing this dial at an angle corresponding to the plane of the ecliptic, so that the line drawn from the centre to the noon hour points to the place of the sun at mid-day, the hour hand points constantly to the sun, and conversely, if the hour hand be pointed to the sun when he is visible, the above line indicates the true south. Subsidiary dials can be added, on the same face. This watch, carried around the world without resetting, would show by comparison with any other watch, adjusted to local time, the exact difference of longitude by mere inspection. *Vice versâ*, the difference in longitude in degrees and minutes would be the difference in time, in hours and minutes. It seems extraordinary that when the French were regulating all their measures afresh, this important concordance was not insisted upon. If it had been, the notation would have grown into favor and by this time have been generally used, whereas the division of the day into ten hours was abandoned, like the arrangement which made the week consist of ten days. It is worth remembering that Laplace, in his *Mécanique celeste*, divided the day into ten hours, that the almanacs of the years II and III of the first French Republic gave the rising and setting of the sun and moon in accordance with the ten-hour notation, and that astronomers often use decimalised time. Thus the tropical year of 365 days, 5 hours, 48 min., 49.7 sec., is conveniently stated as 365.2422338. . . days, and in the



M. DE SARRAUTON'S DECIMALISED DIAL

Annuaire du Bureau des Longitudes for this year there are tables which decimalise seconds, days and years, each separately. Great calculators like Oppolzer use decimals in computing planetary and cometary orbits, and their works sometimes contain tables for reducing the decimal parts of a day into the corresponding hours and minutes.

Many other decimalisations have been suggested and partly carried into practical use, for instance, the decimal arrangement of books on the shelves and in the catalogues of great libraries, initiated, I believe, by chief librarian Dewey, of Boston, Mass., but they may well be left for treatment by other hands.

APPENDIX I.

Summary of replies from twenty-one European countries to enquiries made through Her Majesty's representatives at all European capitals for information on the following three points, and laid before the British Parliament in July, 1900:

1. The ease or difficulty with which the change of systems was made, the manner of introduction of the metric system, and the time occupied in making the change.

2. How far the metric system is satisfactory in its practical operation, and whether there is any desire to return to former systems.

3. What effect the adoption of the metric system has had upon the commerce of the nations adopting it.

AUSTRIA. The law decreeing the change was published in 1872, and came into force January 1st, 1876, there being a transition period of four years. The national press and the scholastic institutions were untiring in their efforts to smooth the way, and the time was found quite sufficient to prepare the public for the compulsory use of the new system. It has been in use for twenty-four years, "gives complete satisfaction, and not the smallest desire is evinced in any quarter to revert to the old and more cumbersome method. . . . It promotes the ease and security of commercial intercourse."

In *HUNGARY* the metric system became quickly naturalised. The law sanctioning it was dated 1st July, 1875, and came into force six months later as an obligatory measure. It has been "of the greatest possible benefit to the commercial life of the nation, not only internally but also in connection with foreign trade. Isolated places exist where grain is still measured by the old method, but such instances are rare."

The Austrian weights and measures had absolutely no resemblance to those of the metric system, which is said to have caused unusual difficulties. They seem to have had a general resemblance to those of the British Isles, and the experience of Austria-Hungary is likely to be paralleled in England.

BELGIUM. Here it took forty years to do away with the old systems, but "it is probable that a shorter period would have sufficed . . . if the law of 1816 had been carried out with greater severity." It is now in general use, and "if an effort were made to return to the old system . . . the attempt would meet with more resistance and encounter greater difficulties than it was ever necessary to overcome in order to establish the system now in force. . . . Trade is conducted without difficulty and with greater rapidity. . . . Disputes have become few and far between." In short, the adoption of the metric system "has done much to ensure honesty in commercial transactions."

BULGARIA introduced the metric system in 1888, to become compulsory in three years. The peasant keeps his old Turkish weights and measures, and weighs his produce by them before he goes to town, but the shopkeeper buys them by the metric scale. Yet there is no desire to return to the old practice. The British Minister at Sophia says: "Several cases have come to my knowledge in which merchants have been deterred from buying what they wanted in England from the incomprehensibility to them of English catalogues, giving only English weights and measures." The Bulgarian Minister of Commerce adds that "the metric system greatly facilitates the curriculum of schools." The population received the law coldly, supposing it would entail great complications and difficulties, but is generally convinced of its "perfection and utility."

DENMARK has not yet adopted the metric system, as the representatives of the peasants "believe it would be unpopular with their electors." It is, however, used for all official reports concerning State railways, as well as in scientific and mineralogical statistics.

In *FRANCE*, the British Secretary says the old measures survived for a long time, but in 1839 the metric system became the sole legal one, and two years and a half were allowed for the change to be effected. He has heard that fifteen months would have sufficed, but adds "no doubt the great development of the press and of education would be a powerful factor in diffusing knowledge of the new system; but, on the other hand, the infinite complexity of modern life would demand a far greater effort to effect the reform than was necessary in 1837."

GERMANY took about three and a half years to introduce the metric system, which "has taken complete root in German commercial life, and its utility has been fully demonstrated." The public, however, still use the old measures of length and superficies, to a large extent. No serious desire exists to revert to the old system, and such a step, if taken, "must inevitably fail . . . the most decisive argument being that none of the old measures belong to the decimal system, the advantages of which are so manifest . . . that a reversion could not be seriously contemplated." "Foreign trade has derived much benefit from Germany's adoption of the metric system, more especially trade between Germany and those countries where the metric system was already in force." Internal trade has received "incalculable benefit."

The S. W. African Protectorate has been ordered to adopt metrical weights and measures, by decree of the Governor of German S. W. Africa, dated Nov., 1899.

GREECE has refrained from rendering the use of the metric system compulsory upon the public, in deference to the habits and prejudices of the people. It is, however, legally established there, but is only used by the Greek Government in the measurement of area and distance—*e.g.*, in the sale of government lands

ITALY had the metric system under Napoleon, but abandoned it on his downfall. Between 1840 and 1870 it was again introduced into several states, which had some 3,000 various weights and measures. The change of system has been very gradual, and in the Neapolitan provinces is still incomplete. There is no desire to return to the old system, for it is felt that "nations which have not adopted the system stand at a disadvantage in commercial dealings with those which have done so, as, other matters being equal, there is a disposition to favor those countries whose system of calculation presents least difficulty."

LUXEMBURG sends a brief but interesting report. To familiarise the people with the new metric system, all the primary schools were furnished with a complete set of the new weights and measures. Though some of the old denominations have been preserved by custom, in spite of the law, there never has been any intention of abandoning the metric system which renders relations with neighboring countries "easier, more sincere, and thus more frequent."

In *MONTENEGRO* the Turkish oke is still used for measuring grain and tobacco, but with that exception, the whole of the commerce of the country is carried on according to the metric system, which was introduced, without difficulty, in 1888.

The *NETHERLANDS* use the metric system, but have retained some of the old names for new weights and measures nearly corresponding to the old ones, which creates a little confusion here and there. The great expansion of trade recently taking place cannot be attributed to the use of the system, since it has grown in equal ratio with Great Britain and the British colonies which have not adopted it.

In *PORTUGAL* the system was gradually adopted, district after district, not to take longer than ten years to introduce over the whole country. The people being illiterate it took a long time to get it into use. Even now 75 per cent. of the population cannot read and write, and old terms are in many cases retained, with some modification in the measures or weights represented by them, to make them exact multiples or sub-multiples of the metric standards. Still, the new system "is regarded as entirely satisfactory by the commercial and industrial classes in Portugal, and there is no desire to return to the various old systems in former use." Again, the report says: "The amount of time saved in commercial counting houses by the simplicity of the metric system . . . is itself a valuable factor . . . It is said that a telegraphic order given in metric terms will always take precedence of an order, from England, for example, expressed in English tons or pounds. . . The school children of Portugal gain many months of time by the omission of the long processes of arithmetic which are necessary for a country with old conventional systems of money, and weights and measures, and the substitution in their place of such subjects as may be more useful commercially, especially foreign languages."

ROUMANIA reports that "the only difficulty met with in the adoption of the new system was the obstinacy with which certain tradespeople adhered for some time to the old order, possibly on account of a vague, though thoroughly erroneous, belief that they would lose by the change. . . At the present time it is in vogue throughout Roumania, and is the only legal system; no tendency is observed of any desire to return to the former system." Locally, however, and very generally, the old unit is preserved as to dealings in land.

In *RUSSIA*, the report says: "The immediate adoption of the metric system is not contemplated, in view of the great difficulties which the low standard of culture existing among the masses of the country would present. The project may be considered only as tentative, in the direction of the ultimate and complete adoption of the metric system in Russia."

In *FINLAND* the high educational level existing greatly facilitated the reform. The metric system has been successfully introduced, after a preparation and education of the masses for its reception in schools, the press, etc. The period of enlightenment extended over two years.

SERVIA briefly reports that it took ten years, from 1873 to 1883, to introduce the new system, which has proved satisfactory in practice and beneficial to Servian trade.

SPAIN took twenty years, from 1849 to 1869, to introduce the metric system, which is to this day not completely in force, there having been a sort of passive resistance, especially as to measures of capacity. The shape of the old measures was preferable to the cylindrical shape of the new ones, which is that adopted. In all the smaller terms, the old system is in vogue, excepting in weight. As for land, official notices, advertisements, contracts, etc., express the equivalents in both systems. But when once the metric system is established anywhere, and the proper weights and measures provided, its employment is continued. The system is considered sure to become universal before long.

SWEDEN introduced the metric system in 1879, but allowed the old measures to continue until 1889. The former did not triumph until it had become the only legal system, but the change was effected without any great difficulty, has shown itself in every way satisfactory in practice, and no desire to return to the old system has been traced. It has had a very good effect upon native commerce.

NORWAY only took three years from 1879 to introduce the system. All public accounts, taxes and customs had to be regulated by it from the start, and its introduction "has been hailed by the commercial classes with much satisfaction. It has on the whole been learnt without difficulty by the lower classes, and has proved both expeditious and well suited to all practical requirements. It is considered that its adoption has facilitated trade. . . A foreign firm using the metrical system will always prefer to deal with another firm which furnishes its weights, prices, and measures in the same system."

SWITZERLAND took less time to put the metric system into operation than any other nation; from July, 1875, to Jan., 1877, only. It has proved very satisfactory and beneficial, the only difficulty having been some reluctance to exchange for the metre the old familiar ell. The same thing happened in the Netherlands, and may be expected in England, in respect to the yard.

TURKEY winds up the procession of continental nations with the admission of failure to keep up with its pace. In 1886 the usual law was passed, fixing as the date for introducing the metric system a period five years from that time, and in 1891 the old measures were destroyed in Constantinople, where alone they were to be compulsory. The difficulty of enforcing a measure so unpopular as this proved to be, upon an ignorant and illiterate people, was thought insurmountable, and the rule was allowed to lapse. Two years ago the kilo was again compulsorily introduced in the same city in place of the oke, but the rule was again quashed in less than a year. The employment of either system is now optional. It was not only the general ignorance which defeated the measure, but the low commercial morality of the dealers, for the new measures, while less than the old, were sold at the same price, and generally called by the same name, which of course was displeasing to the general public.

APPENDIX II.

METRIC TABLES.

The mètré is the ten millionth of the Quadrant from the Pole to the Equator of the Earth, as calculated a century ago. It is

slightly larger than the English yard. Its decimal subdivisions and multiples are :

	English inches.	English feet.	English yards
Millimètre	.0393707904		
Centimètre	.393707904		
Decimètre	3.93707904		
Mètre		3.2808992	1.093633
Decamètre		32.808992	10.93633
Hectomètre		328.08992	109.3633
Kilomètre		3280.8992	1093.633
Myriamètre		32808.992	10936.33

Remeasurements of the quadrant or arc will make very little difference in these figures. The latest now adopted by astronomers gives, by the writer's figuring, the mètre=1.093614 yards. Tables of square and cubic measures are scarcely needed, except as to land, where the unit adopted is the are, which is 10 mètres, or 32.809 feet square, or 1076.43 square feet. The multiple mostly used is the hectare (100 ares) which has superseded on the Continent most of the old measures of land. Our acre of 10 square chains of 66 feet, therefore, contains 40.467 ares, and the hectare is 2.471 acres.

The gramme is the weight of a cubic centimètre of distilled water at freezing point ; 32° Fahr. or 0° Centigrade. Its parts and multiples are :

	English grains, Troy.	English pounds, Avoirdupois.
Milligramme	.01543234	
Centigramme	.1543234	
Decigramme	1.543234	
Gramme	15.43234	.00220462
Decagramme		.0220462
Hectogramme		.220462
Kilogramme		2.20462
Myriagramme		22.0462
Quintal		220.462

It will be seen that another multiple is needed to be an equivalent for that convenient weight, the ton. This may be called the metric or the standard ton, and will equal 2204.62 lbs. avoirdupois.

The litre is the volume of a cubic decimètre, and contains a kilogramme of water at 39.2° Fahr. or 4° Cent. in a vacuum.

	Imperial pints	Imperial gallons
Millilitre	.0017607736	
Centilitre	.017607736	
Decilitre	.17607736	
Litre	1.7607736	0.2200967
Decalitre		2.200967
Hectolitre		22.00967
Kilolitre		220.0967