TGM

A coherent dozenal metrology based on Time, Gravity and Mass

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Preface

There is a widespread belief that mankind invented arithmetic, but long, long before we came on Earth, there were binary stars in the heavens and quadrupeds walked the Earth, each species having its own numbers of vertebrae and teeth. Energy from the stars fell off proportionally to the square of the distance from them. Their circumferences, and those of the Moon and planets, were pi times the distance across them. Dimension is just as fundamental to the Universe as are Time, Space and Energy.

It is a pity that Nature chose that prime number, five, as the number of digits on each of our limbs. It is not a multiple of two or three, so does not normally crop up in calculations unless deliberately or unwittingly put there by us.

Every third number in counting is a multiple of three, yet this vast category skips every power of ten! All over the world every day by rounding off to hundreds, thousands, etc people are rejecting multiples of three for multiples of five.

Simple divisions then give recurring decimals or a rash of fives, and simple ratios become 33⅓% 12½%, etc. Unnecessarily awkward expressions all caused by counting in tens.

Dozenal societies recognise that the real "ten" of counting is the dozen, a natural multiple of two, three, four, or six, while eights and nines multiply to form two-dozens and three-dozens. The aim of TGM is to provide them with a realistic system of weights and measures running in orders of twelve, just as the metric system runs in orders of ten for tens counting.

The reality of a unit is its practical value. Its name and symbol serve to distinguish it from other values. So TGM does not use traditional names for values different to their normal, but new names, coined to suggest their application. Logically applied prefixes and letter groups turn them into a limitless vocabulary that is not too great a strain on the memory.

Its units come from inescapable natural phenomena: light, gravity, electric and magnetic properties of space, but are also well suited to the social needs of everyday life. The gravity foot, called "Grafut" is a little shorter than the standard foot, a slight trim off the length of the metric A4 size paper. A twelfth of it is a small inch, just under 25 mm, and a further twelfth, very close to 2mm, ideal pitch for graph paper.

The square Grafut is a small Square foot, twelve times which is a little over the square metre. The unit of mass is a little over 25 kg. Divided by twelve three times gives just over the half-ounce. 5ml measuring teaspoons accurately dispense 4 TGM units. And so on! You will find many other "handy" values.

TGM preserves the good points of the present rival systems, discarding their flaws and awkward quirks, and brings metrology more in step with natural laws, and counting. It is presented in a form that can easily adapt to foreseeable and unforeseeable needs of the future.

Tom Pendlebury

TGM

A rationalised and coherent system of weights and measures designed to facilitate the full exploitation of reckoning by dozens.

Part One: Spelling numbers in dozens

Every second number is a multiple of two; every third, a multiple of three; every fourth, a multiple of four, and so on. Because two twos are four; two threes are six, two fours are eight, three threes are nine, and three fours are twelve, it is a natural law that the numbers 2, 3, 4, 6, 8, 9 and twelve play the most dominant roles in calculation. They come through in spite of decimalisation:

2 x 0.2 = 0·4. 2 x 0·3 = 0·6. 2 x 0·4 = 0·8. 3 x 0·3 = 0·9, etc.

The lowest common multiple of 0·1, 0·2, 0·3, 0·4 and 0·6 is 1·2, a dozen tenths; and if 0·5 is included, the LCM is 6·0, the half-dozen. Whether counting in units, tenths, sixteenths, hundreds, millions, or whatever, makes no difference. The dozens still dominate, though this is often not obvious due to our writing numbers in tens.

Recognition of this truth has led many individuals, from different nations and generations, to the conclusion that calculation and measurement can be more simply expressed by counting, not in tens, but in dozens. Yet if we still write twelve as "12" which means 1 ten and 2 units, we are not counting in dozens, but in tens. The full benefit can only be achieved by using "10" to mean 1 dozen and 0 units. This is called dozenal numeration.

The counting goes:

1	2	3	4	5	6	7	8	9	↊	↋	*10
one	two	three	four	five	six	seven	eight	nine	ten	elv	zen or onezen.

Since ten and twelve are NOT the same value, we must show clearly when numbers are "spelt" in dozens. That is the purpose of the marker "*"

The digits, ↊ for ten, ↋ for eleven, are those used by the Dozenal Society of Great Britain.

The word "eleven" becomes cumbersome in expressions like "eleven dozen eleven", so it is shortened to "elv".

to continue:

*20 twozen, *30 threezen, *40 fourzen, *50 fivezen etc. stand for 2 dozen, 3 dozen, 4 dozen, etc. They were the words used by Sir Isaac Pitman.

The counting continues (numbers in parentheses are the equivalent "tens spelling"):

*11 onezen one (13), *12 onezen two (14), *13 onezen three (15), etc .... *19 onezen nine (21), *1↊ onezen ten (22), *1↋ onezen elv (23),*20 twozen (24), *21 twozen one (25), etc ...*99 ninezen nine (117), *9↊ ninezen ten (118), *9↋ ninezen elv (119), *↊0 tenzen (120), etc ... *↋↋ elvzen elv (143), followed by *100 which means 1 gross 0 dozens and 0 units. It is twelve times twelve, just as a hundred is ten times ten.

Putting a nought on multiplies by a dozen, just as putting on a nought multiplies by ten in "tens spelling". This gives dozenal counterparts of hundreds, thousands, millions, etc. that look like them, but stand for different values. The job of words is to evoke and distinguish ideas, so these different ideas are given different names, - and on a more straightforward basis. They are coined to suggest the index of the order, - in simple English, how many noughts to put.

Table 1

				Decimal equivalent
ZEN	10	1 nought	*10^{1}	12
DUNA	100	2 noughts	*10^{2}	144
TRIN	1 000	3	*10^{3}	1 728
QUEDRA	10 000	4	*10^{4}	20 736
QUEN	100 000	5	*10^{5}	248 832
HES	1 000 000	6	*10^{6}	2 985 984
SEV	10 000 000	7	*10^{7}	35 831 80
AK	100 000 000	8	*10^{8}	429 981 696
NEEN	1 000 000 000	9	*10^{9}	5 159 780 352
DEX	10 000 000 000	↊	*$10^{↊}$	61 917 364 224
LEF	100 000 000 000	↋	*$10^{↋}$	743 008 370 688
ZENNIL	1 000 000 000 000	*10	*10^{10}	8 916 100 448 256
ZENZEN	10 000 000 000 000	*11	*10^{11}	106 993 205 379 072
ZENDUNA	100 000 000 000 000	*12	*10^{12}	1 283 918 464 548 864
and so on and on				
DUNDUNA		*22	*10^{22}	1·144 754 599 ... x 10^{28}

No one can make a mental picture of a million; it is just a whopping big lot!

HES is also a whopping big lot, only more so. To keep tediously converting numbers from dozenal to decimal just to "understand" them, does not really help. It is only the "spelling" that changes. The number remains the same value, perhaps a tiny unimaginable fraction or a whopping lot. Only the simplest of numbers and fractions, easily convertible, can be pictured in the mind.

Nevertheless, we use numbers to tell us what we cannot figure out without their help. They mainly tell us which is bigger than which, by how much or what factor. Both in decimal and dozenal "300" is greater than "10" by a factor of "30". But whereas in decimal 3 **hundred** is t**hirty** times **ten**, in dozenal 3 **gross** is 3 **dozen** times a **dozen**, - a rather larger ratio on a rather larger number.

Multiplying prefixes, similar to "hecto-, kilo-, mega-," etc., end with the letter "**-a"**

zena= multiplied by zen, **duna**-= x *100, **trina**= x *1000, etc.

Dividing prefixes, similar to "deci-, centi-, milli-, micro-," etc., end with the letter "**-i"**

zeni- a twelfth of, **duni**= divide by *100, **trini**= divide by *1000 etc.

To avoid any confusion with letters used for decimal prefixes, the **abbreviations** are written as numerals. - raised for multipliers, lowered for dividers:

MAZ (TGM unit of mass), abbrev. Mz

1 ^{2}Mz (1 dunaMaz) 1 gross Maz. 1 ^{4}Mz is 1 quedraMaz.

1 $_{3}$Mz (1 triniMaz) Maz divided by *1000. 1 $_{5}$Mz is 1 queniMaz.

No matter how complex a problem, the order of the magnitude is kept track of by adding and subtracting the prefixes, which are in fact exponents. Duna times duna gives quedra. Quena times trina gives aka, but quena times trini = duna.

In multiplication the "-a"s are added and the "-i"s subtracted. For powers the prefixes are multiplied: the square of quena- is dexa-. For roots, they are divided: the cube root of neeni- is trini-. Compare this with the current practice in decimal, in which a trillion multiplied by a quadrillion comes out to an octillion, which is the cube of a billion, and that billion is not the square of a million. but the trillion is. No kidding! That is a genuine example of the parlance now being rammed into our minds by the media and “experts” today!

When multiplying units with numerical prefixes, simply add together the raised ones and subtract the lowered. It is often convenient when working out problems to transfer the prefixes from their units to the figures themselves:

*23 ^{3}Mz x 14 ^{2}Gf becomes ^{3}23 x ^{2}14 MzGf = ^{5}300 MzGf or 3 ^{7}Wg

(Mz, Gf, Wg, units of mass, length and energy. See Part 2).

Values less than one can be expressed in ZENIMALS. Similar to decimals, but “spelt” in twelfths. To distinguish from decimals in this work the **semicolon** is used as the ZENIMAL POINT:

Table 2

Fractions	**Common**	**Decimals**	**Zenimals**
Half	1/2	0·5	0·6
Third, two thirds	1/3, 2/3	0·333.. 0·666..	0·4 0·8
Quarter, three quarters	1/4, 3/4	0·25 0·75	0·3 0·9
Fifth	1/5	0·2	0·2497 2497 ..
Sixth, five sixths	1/6, 5/6	0·166.. 0·833..	0·2 0·↊
Eighth, three eighths,	1/8, 3/8	0·125 0·375	0·16 0·46
five eighths, seven eighths	5/8, 7/8	0·625 0·875	0·76 0·↊6
Nineth; five ninths	1/9, 5/9	0·111.. 0·555..	0·14 0·68
Tenth-	1/↊ (1/10)	0·1	0·12497 2497 ..
Onezen-fourth (sixteenth)	1/14 (1/16)	0·0625	0·09
Twozen-eighth(thirty-secondth)	1/28 (1/32)	0·03125	0·046

Don’t use the “-th” ending on zen, duna, trin, etc. Talk of **zenis**, **dunis**, **trinis**, etc. A twelfth is a zeni, a grossth (horrid word!) a duni , a great-grossth (worse!) a trini. But a **onezen-fourth** is **nine dunis**.

To say “Point five decimal equals point six dozenal” is too long-winded. So the zenimal point is pronounced “dit”:

0·5 = 0·6 “Point five equals dit six” which means, of course, “Five tenths equals six zenis”.

The asterisk, *, marks dozenal numbers where necessary. In long passages a general note such as “All numbers in dozenal” is preferable. In the present work decimal equivalents or parallel examples usually follow the dozenal. They are enclosed in parentheses.

* * * * * *

PART 1 has outlined the method of coping with dozenal counting used in the rest of this book. It is not a textbook for learning dozenal arithmetic, but a system of weights and measures for those already knowing it. If you have not yet reached this stage, the Society has other books to help.

The system in Part 1 is by no means restricted to TGM, and may be liberally used for any other purpose, or as a basic vocabulary for dozenal literature generally. The prefixes may be readily attached to any units, traditional or new: sevaYears, trinaYards, queniVolts, etc. 1 ^{2}cm is a dunaCentimetre, = 1·44 metre.

Part Two: The system TGM

TGM stands for **T**ime, **G**rafut, **M**az, its basic units of time, length and mass. They are based on real phenomena in the world and universe around us.

The names of the units are coined to suggest their applications. Whether in full or abbreviated they should always start with a capital letter, except for prefixes. This allows them to be run together without any dots or hyphens to indicate multiplication: TmGf means Tim multiplied by Grafut. For division "per", /, is used: Tm/GfMz = Tim per GrafutMaz. All units in close formation after / belong to the denominator. Prefixes normally start with a small letter, and the following capital earmarks the root proper: quedriMaz, dunaWerg, etc.

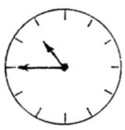
Derived units also are given proper names coined on their applications: Vlos Vl is the unit of velocity, that is, Grafut per Tim, Gf/Tm. Use whichever is most convenient. The square of the Grafut is called a Surf, which makes the square of the zenaGrafut a dunaSurf. The zenaSurf is approximately a square metre.

For comparison examples are given with their parallels in traditional units.

Out of fairness as regards simplicity v awkwardness they are not always strict mathematical equivalents but just analogies. "=" however, means equivalence.

Chapter 1: Time

The regular recurrence of night and day is mankind's chief notion of the passage of time. The day is already divided into two dozen hours, written dozenally as *20. A twelfth of an hour or zeniHour is the familiar five minutes.



Traditional clocks and watches show time in dozenal. The example here clearly shows ten hours and nine twelfths, which in dozenal is ↊·9 Hr. We have grown accustomed to multiply these twelfths by five to get minutes and so say "ten forty-five" and write "10:45".

Even on modern digital timepieces, midday is shown as 12:00, the dozen in decimal, and they revert to 00:00 every twenty-four hours.

In dozenal for pm simply put a "1" in front. 3:50 p.m. is 13·↊ Hr.

Subdividing the hour dozenally gives:

1 zeniHour	$_1$Hr =	5 minutes	
1 duniHour	$_2$Hr =	25 seconds	
1 triniHour	$_3$Hr=	2·1 seconds	(2·08333...)
1 quedriHour	$_4$Hr=	0·21 seconds	(0·1736111... or 25/144)

The last of these is the time unit from which it has been found most suitable to derive a system of practical weights and measures. As it is so fundamental, the "quedri-" is eliminated by giving the unit its own particular name: the **TIM**.

Unit of Time

1 TIM (Tm) = 1 quedriHour = 0·1736111.. second (25/144).**The Fundamental Unit of TGM**.

Minutes and seconds are not used in TGM as they do not correspond to the dozenal subdivisions. However:

100 (hundred) seconds = *400 Tm, and 5 minutes = *1 000 Tm.

In the millisecond range we have the triniTim almost exactly equal to the tenth of a millisecond:

1 triniTim ($_3$Tm) = 0·100 469 4 millisecond.

Going the other way:- Traditional (seconds)

1 Hour	=	10 000 Tm	1 quedraTim	30 600
1 Day	=	200 000 Tm	2 quenaTim	86 400
1 Week	=	1 200 000 Tm	12 quenaTim	604 800
*26 days	=	5 000 000 Tm	5 hesaTim	2 592 000
*265 days	=	50 ↊00 000 Tm	5·0↊ sevaTim	31 536 000
*266 days	=	51 000 000 Tm	5·1 sevaTim	31 622 400

The refinements of modern time-signals and the accurate metering of time by quartz crystals, etc. are automatically absorbed into TGM. Only the method of counting is different. For those interested:

Tropical year (1900) 50 ↊59 905·145 6 Tm 31 556 925·9747 seconds.

Periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of Caesium*↋1 386 58↊ 173 = 1 Tm 9 192 631 770 =1 second.

Neverthless, in the beginning:

Our Mean Solar Day is the first reality of TGM

Try a few examples:- Answers at end of book

1. Write the following times as dozenal numbers of hours: (a) a quarter to eight in the morning, (b) 08:50 hrs, (c) five past two in the afternoon, (d) 22:40 hrs, (e) 22 minutes past five (morning).

2. Hong Kong time is onezen four hours (sixteen) ahead of California. Put the following California times into dozenal, and calculate the respective times in Hong Kong: a) 2 a.m., b) 9:30 a.m., c) noon, d) 5:45 p.m., e) 11:20 p.m.

3. A job took 3 days, 3 hours and 20 minutes. How long is this in dozenal, a) in Hours, b) in Tims?

Chapter 2: From Time to Space

The metre and the foot started from origins quite independent of the second of time- they are arbitrary. The TGM unit of length derives from the TIM by the law of gravity.

Watch a diver dive from a high springboard. His upward velocity gradually falls off until at the top of his jump he starts to fall. Down he comes faster and faster until he enters the water. This changing velocity is called "acceleration due to (Earth's) gravity". Laboratory tests in vacuum (so no air resistance) show this acceleration to be the same for all things, large or small, heavy or light, feather or lump of lead. It is given the symbol "g".

In traditional systems g is 9·80665 metres, or 32·1741 feet, per second per second, and fundamental to a vast number of dynamic calculations though inmany cases not obviously so. To forget it, or multiply when it should be divided can cause much trouble. In TGM it is made the UNIT of acceleration. To multiply or divide by one, or forget to do either, gives the same numerical answer.

Unit of Length

Using TIMs instead of seconds, g is just under 30 cm per Tim per Tim. About eleven and five eighth inches, a little short of a foot. This length is called the GRAVITY FOOT or GRAFUT, abbreviated Gf.

No one invented it. It is a natural phenomenon that comes to light when reckoning in dozens and hours. Whatever unit of length were chosen, g would still have to be defined. So let it be the unit itself and have g = 1 Grafut per Tim per Tim.

For the base of a system of measures it must be very accurately defined. All other units depend on it. Gravity is slightly stronger at the poles than at the equator. This allows **within very narrow limits** a choice of standard best suited for the rest of the system.

Many natural phenomena come close to simple figures when measured by Grafuts:

Mean distance Earth to Moon	$3\ ^{8}$Gf
The lightyear	$2\ ^{13}$Gf
Radius of the electron	$1\ _{11}$Gf
Radius of "stationary" orbit for communications satellites	$4\ ^{7}$Gf
Ten times the Polar diameter of Earth	$1\ ^{8}$Gf

Only the last of these is so close that it gives unit acceleration actually within the narrow polar to equatorial limits of the real g. The polar diameter has been measured to within one part per million. It is a natural phenomenon of gravity pulling the Earth inwards against its internal forces pushing outwards Putting: 1 akaGrafut = exactly ten times the polar diameter of Earthy gives:

1 Grafut (Gf) = 0·295 682 912 metres = 0·970 088 296 ft = 11·641 059 55 inches.

In practical measurement laser beams are now used. Time taken for the beam to go from A to B (or there and back) is measured in precision units. Multiplying by the velocity of light gives the distance. In October 1983 the precision of the metre was redefined by standardising the velocity of light at 299792458 metres per second **exactly**. Precision for our chosen size of Grafut is fixed by:- TGM velocity of light = *4↊ ↋49 923 Grafut per Tim **exactly**.

This is a refinement only and does not alter the practical values of either unit. In general the Grafut is a short foot, the length of the metric (and TGM) A4 size paper, the zeniGrafut, a short inch, and the duniGrafut, just over 2mm (ideal for graph paper). The quedraGrafut is just over 6 km (6·13), a little under 4 miles (3·8). Ten hesiGrafut is just under one micron (0·99).

In **square measure**, the square Grafut, also called the SURF (Sf), is a bit under the square foot (0·94), while the zenaSurf (1 ^{1}Sf) is 1·05 square metre.

The **cubic Grafut**, also called the VOLM (Vm), is eleven twelfths of a cubic foot, just over 25 litres, and about halfway between 6 Imperial gallons and 6 US gallons.

Unit of Acceleration.

1 GEE (G) = 1 Gf/Tm^2 = 9·810 05 m s^{-2}, the TGM STANDARD "GRAVITY".

The metric standard is 9·.806 65 ms^{-2}, usually rounded off to 9·81, 9·8 or just ten in practical work. But ten is outside the real values

Unit of Velocity.

1 VLOS (Vl) = 1 Gf/Tm = 1·7 ms^{-1} = 5·6 ft/s = 3·8 mph. A comfortable walking speed. 8 Vlos is just over 30 mph, 5 Vlos just over 30 kmh^{-1}. 4 duniVlos is the speed of the tape in a cassette recorder.

ACCELERATION DUE TO GRAVITY IS THE SECOND REALITY OF TGM

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EXAMPLES. For comparison these are given in both TGM and traditional. Out of fairness, they are not necessarily strict equivalents.

1) A car travels 4·8 4Gf (17· 5 miles) in 0·7 Hr (35 min). What is its average speed in:

a) ^{4}Gf/Hr (mph), b) Gf/Tm (ft/s), c) Vlos?

*TGM	Traditional
a) 4·8 ^{4}Gf/0;7 Hr = 8 ^{4}Gf/Hr	17·5 mi x 60/35 min = 30 mph
b) 48 000 Gf/7 000 Tm = 8 Gf/Tm	$\frac{17{\cdot}5 \times 1760 \times 3}{35 \times 60} = 44$ ft/s
c) 8 Vlos.	

2) A car runs over a cliff Ƶ8 Gf (145 ft) high. a) How fast is it falling after 10 Tm (2 sec)? b) How far has it dropped by then? c) How long before it drops in the sea? d) What is its downward speed when it hits the water?

a) When it leaves the cliff its downward velocity is nil. G= 1 V1/Tm (32·2 ft/s^2). So after:

10 Tm it will be falling at 10 Vl.	2 sec it will be falling at 64·4 ft/s
b) Av. speed 6 Vl x 10 Tm = 60 Gf	Av. speed 32·2 ft/s x 2 = 64·4 ft.

c) Distance d = av. speed x time t = gt/2 x t = gt^2/2. So t = √(2d/g).

$$\sqrt{\left(\frac{\text{Ƶ8 Gf} \times 2}{\text{1Gf/Tm}^2}\right)} = 14 \text{ Tm} \qquad \sqrt{\left(\frac{145 \text{ ft} \times 2}{32{\cdot}2 \text{ ft/s}^2}\right)} = 3 \text{ sec.}$$

Your turn:- (Answers at end of book)

1) The base of a tank measures 3 Gf x 4 Gf (1m x 1·25 m) and it holds water to a depth of 1·6 Gf (0·5 m). a) What is the volume of water in cu. Gf (m^3) and also in Volms (litres). b) If a pipe empties the tank at 1 duniFlo ($_2$Vm/Tm) (1 litre per second), how long for the tank to empty?

2) A car increases speed from 6 ^{4}Gf/Hr to 14 ^{4}Gf/Hr (24 mph to 60 mph, or 40 to

100 kmh^{-1}) in *20 Tm (4 sec). What is the acceleration in: a) Vl/Tm (mph/s or $kmh^{-1}s^{-1}$)

b) Gf/Tm^2 (ft/s^2), c) in terms of G?

Chapter 3: From Space to Matter and Force

The stuff that makes gravity, and mostly responds to it, is called **matter,** it occupies space, and so has **volume** But the pull, its weight, depends not only on volume. For a given volume, lead is heavier than aluminium, and both are heavier than water, and sink. Wood on the other hand is lighter and floats. The weight depends on the quantity of matter. This is called **mass**.

Mass per unit volume is called **density,** a good guide to the nature of substance, gold or copper? the strength of solutions? etc. It has been found most practical to compare densities to that of the commonest liquid, water. So TGM puts:-

Unit of Mas

1 MAZ (Mz) = the mass of 1 Volm of pure air-free water under a pressure of one standard atmosphere and at the temperature of maximal density (3·98°C)

1Mz = 25·850 355 565 kg 56·990 282 87 lb avoir.

57 lb as near as damn it, just over half a hundredweight, and 4 Maz is about 100 kg, The long conversion figures that keep appearing need not worry the layman. They are needed only to cope with the most stringent accuracy that anyone might require. They are not part of TGM, but links to the old. The author has household and bathroom scales graduated for TGM and weighs direct without worry of kg or lb.

Though the Maz is large compared to the pound, grain or kilogram, this is tomaintain the discipline of 1 1 ratio between basic units, leaving prefixes to display the sense of proportion. In metric the gramme came from a cubic **centi**metre, a **millionth** of a cubic metre. The **kilo**gram (basic unit for SI) starts with a built-in prefix meaning **thousand** but has a water volume about a cubic **deci**metre, only a **thousandth** of a cubic metre, In complex calculations decimal place errors often creep in due to these irregularities.

The zeniMaz is 4 lb 12 oz, a lttle over. 2 kg. The dunimaz is 6⅓ ounces, The triniMaz just over half an ounce, slightly under 15gm. 4 quedrimaz is almost exactly 5 gm. A sevaMaz is just under the megatonne (0·926). 1MTn.= l·0Ɛ6 ^{7}Mz. 3 duniVolm is nineteen fluid ounces, an ounce below the Imperial pint, just over the half litre, and (sorry Americans) 3 ounces over the US pint. For milk and beer we could perhaps call it the "tumblol". *40 of them = 1 Volm.

Unit of Density

1 DENZ (Dz) = lMz/Vm, the S.G of water, = 999·972 kg/m^3

1 kg of water at max. density occupies 1000·028 cubic decimetres, which was the definition of the "litre" until 1964. The CGPM then redefined "litre" as the "synonym for cubic decimetre" but its use "is discouraged for precision measurements". This irregularity, excluded from TGM, causes slight variances between conversion figures for units derived from the kilogram and others derived from the metre. See note on page 39.

THE DENSITY OF WATER IS THE THIRD REALITY OF TGM

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Unit of Force

1 MAG (Mg) = 1 Mz x 1G= 25·859 316 48 kgf = 253·593 265 9 newtons
= 57·010 038 12 lbf = 1834·246 667 poundals

It is the strength required to hold 1 Maz of anything from falling, the weight of 1 Mz,

The traditional systems at this point split into two systems, according to whether the kilogram (or pound) is considered a unit of mass or of weight. 1 newton moves 1 kilogram (mass) with an acceleration of 1 metre per second per second, but 1 kilogram (force), its weight, moves 1 kilogram (mass) with an acceleration of 1 g. Similarly, 1 poundal accelerates 1 pound (mass) at 1 foot per second per second, but 1 pound (force) accelerates its mass at 1 g. In either case, the figures 9·806 65 m/s^2 or 3211741 ft/s^2 are present but hiding behind the words. The intrusive g upsets the apple-cart!

Force can be exchanged for acceleration. Just standing on the ground, you feel your weight as a pressure on your feet. In a lift that starts to go up, this pressure increases. You feel. (and actually are) heavier. As it slows near the top, or starts to descend, you are lighter. Spaceman at take-off are three or four times their normal weight, in orbit, weightless, and on the Moon, only one sixth of their Earth weight. For the same effort (force), they jump six times higher, and take six times as long to come down. But they have not thrown away five sixths of their mass, their bodies. It is the Moon that pulls with only one sixth the Earth's pull. Force is proportional not only to mass, but also to the acceleration it causes. That is why we have 1 Mag = 1 Maz x 1 Gee.

Due to the fact that TGM standard G is very slightly higher than the metric g, conversion figures for the kgf and lbf are slightly different to the mass units.

Standing, sitting, lying, walking, jumping, lifting, carrying, holding, climbing, running upstairs, weight is with us through every moment of our lives. The only escape is to go into orbit; then we sense the abnormality of weightlessness.

WEIGHT (OUR NORMAL EXPERIENCE OF FORCE TO MASS RATIO) is the FOURTH REALITY of TGM

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Unit of Pressure or Stress

1 PREM (Pm) = 1 Mg/Sf = 2900·582 763 N/rn^2 or pascals = 0·420 693 39 lb/in^2

Etymology: PREssure Material or Molecular.

Since 1 VoIm of water weighs 1 Mag, water to a depth of 1 Gf exerts a pressure of 1 Prem on the base of the vessel holding it. In the language of hydraulics, the pressure of water in Prem is always numerically equal to the head of water in Grafuts.

The same applies to any other liquid if wc multiply by its density in Denz. A column of Mercury 2·7 Gf high exerts a pressure of 2·7x11·7 = 2Ɛ·11 Pm.

Similarly, atmospheric pressure depends on the weight of all the air above, and varies with the weather. The molecule of water is lighter than those of either oxygen or nitrogen. So the more moisture in the air, the less the pressure.

A vast amount of phenomena vary with atmospheric pressure. It would be both impractical and confusing to have myriads of tables to cater for every subtle change. A norm is agreed, called the **Standard Atmosphere**, for the swapping of information, deviations for individual cases being adjusted therefrom. Thirty inches of mercury was the original standard, later metricised to the nearest cm namely 76. This then became "de-mercurised' into $dynes/cm^2$ or N/m^2 but nowadays is usually quoted in millibars as 1013·25 mb. In TGM this is 2Ɛ·Ɛ237 Prem. To round this up to 2Ɛ Pm is a shift of less than 2 millibars, and is equally as realistic for a norm. Data has to be converted into TGM, anyway. So:-

TGM Standard Atmosphere I ATMOZ (At) = 2Ɛ Prem

= 1015·203 963 millibars = **1·001** 928 411 decimal Standard Atmospheres

= 29·978 inches or 761·465 mm of Mercury (= 2·6ƧƧ1 Gf,-unimportant)

Within a cat's whisker of the original 30 inch after the metric excursion So you think twozen elv is an awkward number? In yester-language as thirty five it probably was. But this is dozenal. Firstly, it is the product of 5 and 7, the first two numbers less well catered for in dozenal. Very many divisors yield finite zenimals:-

At	Pm	At	Pm	At	Pm	At	Pm	At	Pm	At	Pm
1/2	15·6	1/6	5·↊	1/ ↊	3·6	*1/14	2·23	*1/20	1·56	1/28	1·116
1/3	Ɛ·8	1/7	5	*1/10	2·Ɛ	*1/16	1·Ɛ4	*1/23	1·358		
1/4	8·9	1/8	4·46	*1/12	2·6	*1/18	1·9	*1/24	1·3		
1/5	7	1/9	3·↊8	*1/13	2·4	*1/19	1·8	*1/26	1·2		

Secondly, 2Ɛ is one less than the quarter gross or threezen. The easiest way to divide by 6, for example, is: six into threezen = 6, less one sixth, = 5·↊. Counting upwards, 2Ɛ into gross goes 4 and 4 over. So the dunaPrem = 4 At 4 Pm.

The Prem is also used to measure stress. A steel bar of cross-sectional area 1 duniSurf tensioned by a force of 1 zenaMag suffers a stress of 1 trinaPrem.

Examples. dozenal	decimal
1) A bar of iron measures 2x3x*40 $_1$Gf (	50mm x 75mmx1m).
What is its mass? Density of iron = 7·ƐDz	(7900 kg/m).
200 $_3$Vm x 7·Ɛ = 13↊0 $_3$Mz = 1·3↊Mz.	0·003 75 m^3 x 7900 = 29·625 kg.

Note that zeni x zeni x zeni = trini.

2) What is the pressure of water on the floor of the tank in Exercise 1 Chap, 2?

dozenal	decimal
Vol of water = 16 Vm	Vol = 0·625 m^3
Weight = 16 Vm x 1 Dz x 1 G	Wt. = 0·625 m^3 x 1000 kg/m^3
= 16 Mag.	x 9·806 65 m/s^2 = 6129·156 N
Base area 10 Sf	Base area = 1·25 m^2
Pressure = 16Mg/10 Sf = 1·6 Pm.	Press. = 6129·156 N/1·25 m^2
Short method: Depth = 1·6 Gf so	= 4903-325 N/m or pascals
pressure = 1·6 Pm.	= 49·033 millibars.

3) A man "weighs" 3 Mz (75 kg) and is sitting in a car which decelerates from 14 Vl to 8 Vl (100 to 50 km/h) in 16 Tm (3 sec). By what force does he feel himself thrust forward? (In English we "weigh" usually to measure mass, not weight).

dozenal	decimal
So Force = 3 Mz x 0·54G= 1·4 Mg	Force = 75 kg x 4·63 -m/s^2 = 347N

Exercises

dozenal	decimal
Deceleration = $\frac{14 - 8 \text{ V1}}{16 \text{ Tm}}$	Deceleration = $\frac{100 - 50 \text{ km/h}}{3\text{s x}3600 \text{ s/h}}$
= 4/9 = 0·54 Mg	= 4·63 m/s^2

1) A bar of aluminium "weighs" 0·4 Mz (2 kg). The density of aluminium is 2·8 Dz (2700 kg/m^3).

a) What is the volume of the bar? b) If it is 2·3Gf long (750 mm), what is its cross-sectional area?

2) A "weight" of 3 Maz (75 kg) is on one end of a piece of rope, which passes over a large pulley. A 5Mz (125 kg) "weight" is on the other end, and at first held from descending, then let go. What is the acceleration of the system? Formula: Acceleration = force/mass. Hint: Mass to be moved is the sum of the masses (ignore rope andpulley), but driving force is their difference x G.

3) A man "weighs" 3·26 Mz (83 kg) and each of his feet covers an area of 0·36 Sf (0·0255 m^2). What is the pressure in Prems (N/m^2) on his feet when standing evenly on both?

4) A hotwater tap in a kitchen is 14 Gf (4·7m) lower than the surface of the water in the filler tank in the house loft. What is the pressure in Prems (N/m^2) at the tap?

5) A metal bar of cross section 7 $_3$Sf (0·6 sq in) was loaded till it broke. This took 3 ^{2}Mg (10·5 tons). What is the tensile strength of the metal in Prems (lb/in^2)?

6) What is the approx. equivalent in avoird. (metric) of a) the zeniMaz, b) the duniMaz, c) the triniMaz, and d) the quedriMaz?

Chapter 4: Work, Energy, Heat and Power

To move things we push, pull, lift or let drop. All require force, the force of gravity in the last case.

If a thing is very heavy and rests on a rough surface, and we are trying to push it uphill, we can apply considerable force without moving it, but we have not done any work on it until we have moved it. Moving it six yards is twice the work of moving it only three. Work is proportional to both force and distance.

The amount of work done is also a measure of the energy required to do it. So in TGM:

Unit of Work or enERGy, 1 **WERG** (**Wg**) = 1 Mag x 1 Grafut = 55·3 foot-pounds

= 74·983 195 487(say 75) metre-newtors, usually called joules.

Energy exists in various forms, mechanical, electrical, heat, nuclear, etc. It can be transformed from one to another, as the experiments of Joule showed when he discovered the mechanical and electrical equivalents of heat. Nowadays calories, of which there were several kinds, have been superseded by the Joule. The Werg is similarly used to express work or energy of whatever kind.

Potential Energy.

When energy is not working, that is causing change, it is stored. It takes fourzen Werg to raise six Maz to a height of eight Grafut. When let go, fourzen werg is expended in the opposite direction to bring it down to earth. But while suspended at eight Grafut, by its mass, its height and the fact that Earth's gravity is pulling, it is holding the potential to do that fall. This is called Potential Energy, = mass x altitude (from a chosen datum), x G.

Kinetic Energy

When a man on a bicycle is freewheeling though his and the bicycle's mass are traversing distance, because no more force is being applied, no energy is being spent. But to bring him to a standstill requires braking energy, How much depends on the mass and the velocity. Force = mass x deceleration, so twice the force will stop him in half the distance, but force x distance will come to the same amount of energy.

If his velocity goes from v to zero in time t, force = mv/t. Average velocity during braking is v/2, and distance covered vt/2. So:

Force x distance = mv/t x vt/2 = $mv^2/2$ This is called Kinetic Energy.

6 Maz at 4 Vlos has a kinetic energy of (6 Mz x 14 Vv)/2 = 40 Werg. .

(Vv stands for Vlov, unit of velocity squared = Vl^2)

Heat

Traditional heat units were the amounts required to raise 1 unit mass of water by 1 thermometer degree:

1 B.T.U. (British Thermal Unit)	raises 1 lb of water through 1° F
1 C.H.U. (Centigrade Heat Unit)	raises 1 lb of water through 1° C
1 cal. (calorie)	raises 1 gm of water through 1° C
1 Cal. or kcal. (large or kilocalorie)	raises 1 kg of water through 1° C

These put the specific beat of water at a neat 1 in their systems, but give no clue as to how many joules or foot-pounds of energy are required, usually the very information wanted. Actually, it takes a little more energy per degree near freezing and boiling points, reducing to aminimum between 34 and 35°C.

To raise 1 Maz of water from freezing to boiling takes 6Ɛ7·7 dunaWerg at 2Ɛ Pm. In decimal, this is

1003·6 to cover 100·054 kelvin or degrees C. So 1 dunaWerg raises 1 Maz by very slightly under 0·1 kelvin on average. As the specific heat varies however, there is no reason why the decikelvin should not form the basis of the TGM temperature scale:

Unit of Temperature

*100 CALG or 1 dunaCALG (^{2}Cg) = 0·1 kelvin. (Etymology: CALorific Grade or deGree)

This gives the **specific heat of water as 1 Werg per Maz per Calg** for general work, maintaining the 1 : 1 ratio for basic units, while at the same time making easy the conversion of data from traditional sources:

To convert kelvins to dunaCalgs, simply multiply by ten and dozenise

20 K: 200 that is *148 dunaCalgs. 36 K: 360 that is *260 dunaCalgs.

Temperature zeros

The Centigrade (properly called Celsius) scale counts from the freezing point of water, but various phenomena, particularly the behaviour of gases, indicate that the very lowest possible temperature is 273·15 degrees lower than this. It is called Absolute Zero. Both kelvins and Calgs count from absolute zero.

Ice Point, 0°C = 273·15 K = 2731·5 dK that is 16Ɛ7·6 ^{2}Cg

Even when temperatures are read on the Celsius (or Fahrenheit) scale, they have to be converted for absolute zero if multiplication or division is involved. So having zero for Ice Point and 100 for Boiling Point amounts to nothing more than a pretty idea for popular use.

Dozenists may invent a new scale running from 0 to *100 for freezing to boiling, but will it help? For TGM the best popular scale is the present Celsius multiplied by ten and dozenised.The tenth of a degree we will call a **decigree abbreviation d°:-**

	°C	d° dec.	d° doz.
Ice Point	0	0	0
Room temp	20·4	204	**150 Standard for Room Temperature**.
Blood heat	36·9	369	269
B.P.water	100	1000	6Ɛ4 for metric standard atmosphere.
B.P. at 2Ɛ Pm	100·05	1000·5	**6Ɛ4;6 Standard B.P. for TGM**

We can memorise B. P. as *700 - 7 or (dec) 1000 + 1 decigrees. And 36·9 converting to a nice *269 for blood heat should be easy to remember.

To convert decigrees to dunaCalgs we must add *16Ɛ7·6 which is 4·6 short of *1700.

B.P. water 6Ɛ4·6 decigrees is*1700+6Ɛ0 = **21Ɛ0 dunaCalgs**.

For most work the 4·6 can be considered 5, which is half a degree. So, in general **to convert Centigrade straight to dunaCalgs:**

1) Knock off half a degree and multiply by ten,

2) dozenise the number,

3) add *1700.

Blood heat 36·9.. put 364 = *264, add *1700, = *1964 ^{2}Cg.

Temperature differences. In rises and falls the count is from one temperature to another and where the zero is does not matter. A rise of 20 C-degrees is a rise of 20 kelvin, and a rise of *300 decigrees is a rise of *300 dunaCaIgs.

A full Celsius-cum-Deeigree thermometer scale is shown on page 52.

To return to energy:

Specific heat of water = *100 Wergs per decigree

= *Ƨ00 Wergs per C-degree.

Latent Heat.

When a pan of water is "brought to the boil" its temperature rises up to, but not beyond, boiling point. If the heating is then turned down, it can be made to "simmer". Or the heating can be left full on, making it "boil vigorously". It then "boils dry" sooner. This extra energy, which does not raise the temperature but turns water into steam, is called latent heat of vaporisation. It takes the same amount to vaporise each Maz of water, providing the atmospheric pressure stays put.

Latent Heat of vaporisation of water at 2↋ Prem = 3·162 314 ^{5}Wg/Mz

roughly five times as much as was needed to raise it from freezing to boiling.

For similar reasons ice is slow to melt, even when the environment is quite warm. The solid ice has to take in a lot of energy just to change into liquid water before any rise in its temperature:

Latent Heat of fusion of ice = 5·6690 ^{4}Wg/Mz

Changes of atmospheric pressure merely due to weather are not great enough to have any noticeable effect on this.

ABSOLUTE ZERO AND THE SPECIFIC HEAT OF WATER ARE THE FIFTH AND SIXTH REALITIES OF TGM.

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Power.

Whatever the kind of energy, how quickly it can be produced, transported or consumed, is a question of power.

Unit of Power, 1 POV (Pv) = 1 Werg per Tim.

It equals 431·903 201 9 joules per second, also called watts. 432 happens to be 3 gross, so we find that 1 duniPov ($_{2}$Pv) = 2·999 327 791 watts, which is 3 watts for almost all practical applications.

The Pov is just over half a horse-power, 0·579 HP.

Unit of Power Density, 1 PENZ (Pz) = 1 Pov per Surf = 4940·079 876 W/m^{2}, just under 5 kilowatts per square metre. Its use is for energy that flows or radiates through substances or space.

Examples.

1) A mass of 8 Maz (4 cwt, 200 kg) is raised by rope and pulley to a height of *40 Gf (48 ft, 15 m) above the ground. If the other end of the rope is attached to some load, a) How much work can be done by its descent to ground level? and b) How much potential energy would the same mass have at the same height above the surface of the Moon? (Moon's g = 0;2 G)

a) Earth's gravity = 1 G,	4 x 112 lb = 448 lbf
so force = 8 Mg.	200 kg x 9.8 = 1960 newtons.
Potential energy = 8 Mg x 40 Gf	448 x 48 ft =21504 ft-lb.
= *280 Wg.	1960 x 15 m =29400 joules.
b) Moon's g = 0·2 G, so force is one sixth:	
*280/6 = *54 Werg.	21504/6 = 3584 ft-lb.
	29400/6 = 4900 joules.

2) A car "weighs" *30 Maz (18 cwt, 1000 kg) and is travelling at 8 Vlos (30 mph, 48 km/h). What is its kinetic energy? (E = mv^{2})

3) A drum of oil weighing ↊ Maz (5 cwt, 250 kg) is lifted 6 Gf (6 ft, 2 m) in *16 Tm (3 sec.). What was

the power required?

Force to overcome gravity:-

Ƨ Mz x 1G= Ƨ Mag

*30 x (8 Vl)2/2

=30 x 54/2

= *800 Wg

This example shows the simplification by having G= 1, and 1 hour= *l0 000 Tim.

5 x 112 x 1 g = 560lbf.

250 kg x 9·8 m/s^2 = 2450 N.

Mass = weight/g

= 18x112 lb/32·2 = 62.61 lb)

30 mph = 44 ft/s. v^2 = 1936 ft^2/s^2

Energy = 62· 6 x 1936/2 = 60597 ft-lb

48 km/h = 13·3 m/s. v^2 = 177·7 m^2/s^2

Energy = 1000 kg x177·7/2

= 88·9 Megajoules.

Energy required:

Ƨ Mz x 6 Gf = *50 Wg

Power:-

*50 Wg/16 Tm = 3·4 Pov

560 lbf x 6 ft = 3360 lb-ft.

2450 N x 2 m = 4900 J.

4900 J/3 s = 1633·3333... watts.

3360 lb-ft/3 s = 1120 lb-ft/s.

4) An electric motor has a power rating of 7 Pov (3 kW). Howmuch work can it do in: a) 1 zeniHour (10 min), and b) ten hours?

a) 7 Pv x 1 ^{3}Tm = 7 ^{3}Wg

3 kW x 600 s = 1800 kJ.

b) 7 Pv X Ƨ ^{4}Tm = *5Ƨ ^{4}Wg

3 kW x 10 h = 30 kWh

30 kWh x 3600 s7h-= 108 megajoules.

The reader is left to find the answer in pound-feet.

5) A 1 zenaPov (5 kW) immersion heater in a water cistern 1·6 Gf diameterx 3 Gf (0.4 m dia x 1 m). The (futuristic) thermostat is set to cut out at *360 decigree (50°C), and the temperature of the water before switching on is *130 d° (18°C).

How long before the thermostat cuts out? [π = 3;18 (3.14)]

Vol = 3 x 3·18 x 0·9^2 = 5·37 Vm

So mass of water = 5·37 Mz

Temperature rise = *360 - 130 = 230 ^{2}Cg

Heat required = 5·37 x 230 = ƐƐ0·9 ^{2}Wg

Time = ƐƐ090 Wg/10 Pv =ƐƐ09 Tm,

say 1 Hour.

1 x 3.14 x 0.2^2 = 125·6 litre

Mass = 125·6 kg

50° - 18° = 32 degrees

125·6 x 32 x 4190 (sp. heat) = 16·84 MJ

16·84 MJ/5 kW = 3368 seconds

0.9356 hour

Exercises.

1) A fork-lift truck lifts a box of goods weighing *16 Mag from a height of Ƨ Gf up to *16 Gf.

a) How much energy has it spent on doing this?

b) What potential energy (from ground level) has the box of goods at that height?

c) If it then falls, at what velocity does it hit the ground?(Tip: acceleration is at 1G from zero to final, so average velocity = half the final).

d) What is its kinetic energy on hitting the ground? ($E=mv^2/2$)

e) Assuming it is unbroken (!) and it takes a force of 8 Mag to push it aside, how much energy is spent in moving it *20 Gf?

f) Where has this energy gone?

g) Do the whole problem again in metric using: 450 kg, 2·5 to 3·25m, g=9·8 m/s^2, side push 2 kN, x 8m.

2) A container was closed up at normal atmospheric pressure when the temperature was *130 degrees (18° C), The building in which it was stored caught fire during which its temperature ran to *1300 d°

(216° C). Assuming it remained intact and sealed, what was the internal pressure a) in atmospheres, and b) in Prem (N/m²), at that temperature? (Formula: $p_2 = p_1 \times T_2/T_1$. Absolute temperatures must be used). Work to three significant figures.

Angles. Rotation, Radiation and Perspective

Just as minutes and seconds of time do not fall into the strict order of dozens. so neither do-degrees, minutes and seconds of angle. They would cause just as many complications in dozenal as they do in decimal.

Apart from the arbitrary 360° system, tradition has another method, essential to engineering and science, based onthe two natural elements π (pi) and the RADIAN.

Most people know PI, the Greek letter π, which represents the number of times a circle's diameter will go into its circumference. In decimal It is 3·141 592 .... Unfortunately, It is an unending non-repeating fraction in every counting system and cannot be otherwise. Nevertheless, it is a reality of all circles, and something which has to be coped with, whether we like It or not.

In dozenal, π= 3·1848 0949 3Ɛ etc.

The RADIAN is not so well known. A rolling object of say 1 Gf radius turns through an angle of 1 radian for every Grafut it travels. a natural 1 : 1 ratio. (Still true whether you use metres, feet, or anything else). When it has turned full circle, it has travelled 2π Gf, and turned through an angle of 2π radians.

So in scientific and engineering works, full circle is often representedby 2π, "radians" being understood. Similarly, 180° is written as π. 120°as 2π/3, 90° as π/2, 60° as π/3, etc. In zenimals these are: 2π, π, 0·8π, 0·6π, 0·4π., etc.

They are in fact zeniPis:

zeniPis: ^{v}1 ^{v}2 ^{v}3 ^{v}4 ...^{v}9, ^{v}Ƨ, ^{v}Ɛ, 1^{v}0 1^{v}2 etc

traditional: 15° 30° 45° 60° ... 135°, 150°, 165°, 180°, 210° etc

They are the angles most commonly required in geometry and other work.

The downward pointng angle sign (or small v) gives a compact- notation for slipping into the corners of diagrams, and serves as a zenimal point. 1^{v}4 means 1·4π radians.

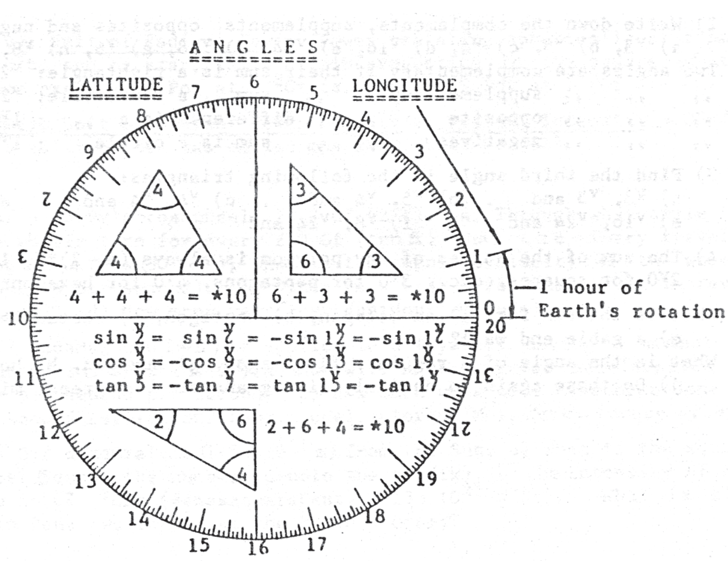
ZeniPis are then divided into duniPis, triniPis, etc. ^{v}04 = 5°, ^{v}08 = 10°,etc. So all the major divisions of thetraditional protractor are still catered for exactly.

Note that:

1) **opposite angles** differ by a simple 1, instead of having to add or subtract 180°. 1^{v}2 is opposite ^{v}2. ^{v}9 is opposite 1^{v}9.

2) The sum of the angles of any triangle is always 1^{v}0.

3) For the supplementary angle (the difference to make up to 180°) subtract from 1^{v}0. This gives the



dozenal complements: $^{v}1$ and ^{v}Ɛ, $^{v}2$ and ^{v}Ƶ, $^{v}3$ and $^{v}9$, etc. This simplifies the use of trigonometrical tables:

Functions of $^{v}1$, ^{v}Ɛ, 1$^{v}1$, 1^{v}Ɛ,have the same numerical value.

Also those of $^{v}2$, ^{v}Ƶ, 1$^{v}2$, l^{v}Ƶ. Then $^{v}3$, $^{v}9$, 1$^{v}3$, 1$^{v}9$, and so on.

4) Although the system is of the degree type, yet it is at the same time virtually in radians. $^{v}04$, 4 duniPi, is also 4π duniRadians. To get the actual number, multiply out by the numerical value of π:

$^{v}1$ = 0·1π = 0·31848 radian. $^{v}6$ = 0·6π (the rightangle) = l·6Ƶ24 radian. $^{v}005$ (0°31′15″) = 5π triniRadian = 13·85Ɛ4 $_3$Rn

$^{v}082$ (10°12′30″-)   *82 triniradian = 217·Ƶ614 $_3$Rn

With any other kind of gradations, when converting to radians, not only do you have to multiply by π, but also to divide by the number of gradations to the semicircle. In traditional also to convert minutes and seconds to degrees:

10°7′30″ = 10°·125 = 10·125/180 x 3·14159 radn = 0·1767 radn.

5) The zeniPis of longitude match up with the hours of the solar day, and so with the basic Standard Time zones around the world. On the celestial sphere zeniPis match up with the sidereal hours of Right Ascension. In traditional astronomy, 1 hour 1 min 1 second of R.A. = 15 degree 15 min 15 sec of angle.

The humbug of subtracting 180 or 360, or subtracting from them, or having to divide by 180, 60 or 3600, is a thing of the past in TGM. Except for π (which cannot be helped),. everything runs straightforward in dozenal numbers.

Exercises.

1) Write the following angles in PI notation, e.g. 15° = $^{v}1$, 5° = $^{v}04$, 240° = 1$^{v}4$:

45°, 15°, 10°, 5°, 20°, 25°, 65°, 75°, 80°, 22·5°, 2·50, 7°30′, 1°15′, 120°, 190°, 270°, 300°, 325°.

2) Write down the complements, supplements, opposites and negatives of:

a) $^{v}3$, b) $^{v}5$, c) $^{v}4$, d) $^{v}16$, e) $^{v}04$, f) $^{v}18$, g) $^{v}6$, h) $^{v}8$, i) 1$^{v}4$.

Two angles are complementary if their sum is a rightangle: $^{v}2$ + $^{v}4$ = $^{v}6$

two angles are supplementary if their sum is a semicircle: $^{v}2$ + ^{v}Ƶ = l$^{v}0$

two angles are opposite if their difference is a semicircle: 1$^{v}2$ -$^{v}2$ = l$^{v}0$

two angles are negatives if their sum is a circle: l^{v}Ƶ = -$^{v}2$

3) Find the third angle in the following triangles:

a) $^{v}3$, $^{v}3$ and... b) $^{v}5$, $^{v}4$ and .... c) $^{v}4$, $^{v}4$ and ...d) $^{v}1$ $^{v}7$ and ... e) $^{v}16$, $^{v}24$ and ... f) $^{v}8$, $^{v}24$ and ...

4) The sum of the angles of any polygon is always (n - 2)π, 1$^{v}0$ for triangles, 2$^{v}0$ for squares, etc., 3$^{v}0$ for pentagons, 4$^{v}0$ for hexagons, and so on.

What is the sum for: a) an octagon, b) heptagon, c) rectangle, d) parallelogram, e) a gable end wall?

What is the angle of a regular: f) octagon, g) hexagon, h) heptagon, i) nonagon? j) Do these again in decimal, giving answers in degrees, minutes and seconds.

Rotation and Radiation.

Units concerned with these often involve the concept of division or multiplication by a radius, plain, squared or cubed, for which TGM offers the prefixes:

RADI- divided by radius	RADA- multiplied by radius
QUARI-square of radius	QUARA-square of radius
CUBRI-cube of radius	CUBRA-cube of radius

In abbreviations use the initial letters. They can be put upstairs/downstairs like the numercial prefixes, or, on line, using capitals for multiplying, small letters for dividing:

^{Q}Mz or QMz quaraMaz, $_{Q}$Sf or qSf quariSurf, $_{R}$G or rG radiGee. They can be added, subtracted, or cancelled out, etc. :

R/R, Q/Q, C/C, r/r, q/q, c/c and R x r, Q x q, C x c, all cancel out to 1.

RxR or R/r = Q.   rxr or r/R = q.   q/R = c, etc.

QMz (Moment of Inertia) x rG (angular acceleration) = RMg (torque).

RadiGrafut (or radifut) (**rGf**) turns out to be just another name for the radian. RadiGrafut literally means **Gf**(circumferential)/Gf(**rad**ial). The abbreviation rGf with its r for cancelling, etc. can be more convenient than the traditional Rn.

QuariSurf (**qSf**) is the steradian, **unit of solid angle**, a pyramid or cone shape such that the cross-sectional area (spherical) is always equal to the square of the distance from the apex. qSf often more convenient than the traditional Sr.

RadiVlos (**rVl**), velocity/radius, is the **Unit of Angular Velocity**. 1 radian/Tm

RadiGee (**rG**), **Unit of Angular Acceleration**. 1 radian per Tim per Tim.

RadaMag (**RMg**), **Unit of Torque**, that is force applied to turn a wheel or shaft, etc., which is more effective the greater its distance from the centre. (In the traditional systems it is expressed in "pound-feet or "newton-metres" supposed to distinguish it from energy expressed in "foot-pounds" or "metre-newtons" = J).

QuaraMaz (**QMz**), **Unit of Moment of Inertia**. We all know that mass tends to stay put or keep going, i.e. inertia. In rotation its effect is proportional to the square of its distance from the centre.

QuaraPov (**QPv**), **Unit of Radiant Power**. Power radiating spherically as from a candle, light bulb, sun or star. falls off in proportion to the square of the distance. So, for example, 1 Pov at 3 ^{8}Gf is equal to 9 pov at 1 ^{8}Gf.

QuaraPenz (**QPz**), **Unit of Radiant Power Densit**y or **Radiant Intensity**,= QPv/Sf (In the first edition this was called the PRAD, Unit No. 34)

Exercises.

5) The radius of a lorry's roadwheels is 2 Gf (2ft). a) Through what angle (in radians) do the wheels turn for every *10 Gf (ten ft) that the lorry travels? b) If it is going at 7·4 Vlos (30 mph), what is the angular velocity of the wheels in radiVlos?(radians per second). c) Since 2π = 6·35 (6·28) what is it in revs. per Tim (per second)? d) How many revs. per duniHour? (ninute).

6) A torque of 7 radaMag (400 lbft) is applied to a flywheel having a moment of inertia of 6 quaraMaz (340/32·2 lb-ft^2) a) What will be the angular acceleration in radiGee (radians per second per second)? h) How much work will have been done by the end of the second revolution? (Ang. accel. = torque/MoI. Work= torque x radns)

7) The Earth is 8·2 dexaGrafuts (1·5 x 10^{11} m) from the Sun. a) What is the square of this distance? (Square the number, double the prefix). b) The intensity of the Sun's radiation 16·ƧƧ ^{18}Qpz, (zenakaquaraPenz) (3·13 x 10^{25} W/Sr) . What is the power density in Penz (watts/m^2) at the Earth's orbit?

Reciprocal Units, the prefix PER

Frequencies are usually expressed against time. as so many per Tim (or sec., min. or hour). But sometimes in the theory of Light, etc. it is quoted in inverse wavelengths, as so many per metre. The convergeance or "strength" of lenses is measured in "dioptres". Two dioptres means a focal length of half a metre. Three dioptres, of a third of a metre, etc.

The fineness of a grating. etc. depends on "how many per Surf'. The compactness of a solid, on how many (molecules) per Volm. etc. So in TGM as convenient, the prefix PER- may be used on any of its units, for example:

1 PERFUT (PGf) = 1/Gf = 3·382 dioptres or per metre

R_∞ Rydberg's constant = 1·1058 Ɛ48Ƨ hes Perfut (or hesaPerfut, ^{6}PGf)

=(1·097 373 1 x 10^7 per metre)

If you don’t understand this, not to worry. But the system must cater for those who do.

(Don’t abuse this prefix. it should only be used when the numeratoris a plain number. Surf per Tim is Sf/Tm, NOT SurfPerTim SfPTm.)

Perspective and Angular Size.

As we watch an object retreat, after the first few yards, both width and height appear to diminish in proportion to the distance. At twice the distance the image appears half as wide and half as tall, so overall only one quarter the area.

Area diminishes in proportion to the square of the distance.

This is a practical example of the eye, human, cat’s, cattle’s or otherwise, using the radian and steradian.

1 Grafut viewed at a distance of 1 **duna**Grafut spans an angle of 1 **duni**Radian.

At 1 **hesa**Grafut it spans 1 **hesi**Radian, and so on.

4 ^{6}Gf at 3 ^{8}Gf spans 1·4 $_{2}$rGf (divide the numbers: 4/3 = 1·4, and subtract the prefixes: 6 - 8= -2), and those are the actual diameter. the mean distance and the angular diameter of the Moon as seen from Earth.

In traditional these are 3500 km, 380 000 km and 31’40”. But 3500 km divided by 380 000 km = 0· 009 211 radian. The minutes and seconds are an unnecessary complication.

The Sun’s angular diameter is also 1·4 duniRadian, and its actual diameter is ↊·↋ akaGrafut. This gives:

Mean distance Sun to Earth = ^{8}↊·↋/$_{2}$1·4 = 8·2 $^{↊}$Gf (dexaGrafut)

Astronomers call this the Astronomical Unit and use it as a unit of length. In TGM it is Auxiliary Unit No 3,1:

1 ASTRU (Au) = Mean distance Earth to Sun = 8·207↊ 4205 $^{↊}$Gf (from the handbook of the British Astronomical Association, 149 597 870 km),

Parallax.

This is perspective turned the other way round. A distant point is observed from two separate viewpoints near at hand:

Distances of the nearer stars are measured by taking two observations six months apart. During this time the Earth has moved to the opposite side of its orbit, a lateral shift of two Astrus, so:

Difference of angular position divided by 2 = Parallax relative to 1 Astru.

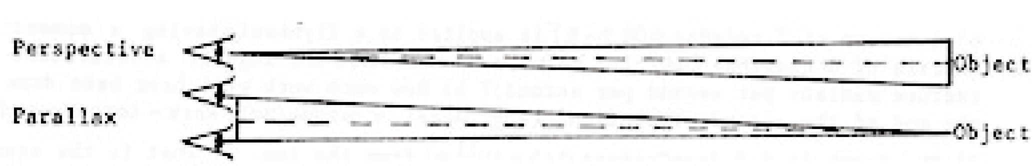
A parallax of 1 **hesi**Radian (difference was 2) means a distance of **hes** Astrus.

a parallax of 1 **sevi**Radian means a distance of **sev** Astrus.

And so on. The smaller the angular difference,the greater the distance:

14 $_{6}$rGf gives 0·09 ^{6}Au. i.e. 9 ^{4}Au. 8 $_{7}$rGf gives 0·16 ^{7}Au, i.e. 16 ^{5}Au.

(Transfer the prefix from “downstairs” to “upstairs” and find the reciprocal of the number). **Astru**, of course, means “times the distance to the Sun”.



Traditionally, the angles are measured in seconds instead of micro-radians.

This leads to yet another unit of length, the parsec, the distance corresponding to a parallax of 1 second. There are 206 265 Astronomical Units to the parsec, and that is the number of seconds in a radian! In TGM no seconds, no parsecs.

Exercises.

8) A car is 6 Gf wide and 5 Gf high (6 ft, 5 ft). When it is at a distance of 2 ²Gf (100 yards), what is: a) its angular width and height in rGf (radians)? and b) its angular area in qSf (steradians)?

9) The nearest star, Proxima Centauri, has a parallaxof Ɛ·00 $_6$rGf (0″·76). What is its distance in Astrus (A.Us.)?

Chapter 6 : Electrical Units

A brief glimpse at what's what.

The real unit of electricity is the **electron**. Whether it is actually a particle, or a tiny bubble of standing wavelets of space, no one knows. But we know OF it by its manifold activities, for it appears that hardly anything is, or occurs in the whole universe, without its playing an important role, –- this includes you and me.

Electron repels electron. Probably the reason why they are always on the move. They are said to have a **negative charge**. Nuclei of atoms have a **positive charge**, and attract electrons up to a certain number depending on the strength of that charge. Hydrogen takes only one electron, helium two. while oxygen takes onezen four. Chemical elements and their combinations depend almost entirely on electricity. The electrons do not plop straight into the nuclei, but circulate in tiny orbits.

Apart from the electric stability of atoms (i.e. having the right number of electrons for their charge). there is also a symmetrical stability, the grouping of electrons into "shells" – a sort of club arrangement with a quota of members. Those with the exactly right number, are the **noble gases**: helium, neon, argon, krypton, xenon.

Atoms having one or two electrons above these club quotas, tend to let their "unwanted" members wander off to visit neighbouring atoms. They are conductors, and the best conductors are the metals. When you say a thing "looks like metal", what you are seeing is clouds of electrons swarming like gnats on the surface, – **metallic lustre** is the technical name.

Places where electrons are crowded are at a more **negative potential**. Where they are in short supply, a more **positive potential**. Potential is to electricity, like temperature to heat, or pressure to a water supply. Traditionally it is measured in volts.

Electrons flow from negative (overcrowding) to positive (short-supply). The terms "positive" and "negative" were allocated arbitrarily before the electron was discovered or the true nature of electricity understood. The convention sticks.

Conventional **current** flows positive to negative, **electrons** negative to positive.

Current is traditionally measured in amps.

Atoms that are an electron or two short of the "club quota", hang on avidly to those they have and also tend to "borrow" any electron that comes near. They resist the liberal flow of electrons, and are called insulators.

In between are atoms with half-filled shells. They work both ways according to circumstances and are called **semiconductors**: carbon, silicon, germanium, etc. Very important in the elctronics industry, giving us names like **resistor**, **transistor**, and **silicon chip**.

While electrons are "off parade", the atom as a whole has a positive charge, and is called a **positive ion**. If "guest" electrons are present, it is called a **negative ion**.

The general disposition of orbits filled by electrons determines the **colour of a substance**, which rays of light it will reflect, and which absorb. When an electron drops into an orbit, or falls from a higher orbit to a lowerg a blip of **light** or **x-ray** is emitted. Each manoeuvre has its own individual colour or **line in the**

spectrum. Objects **glowing** or bursting into **flames**, have this happening to vast multitudes of their toms.

Just as that peculiar stuff we call "space" can transport the attraction we call "gravity" from one thing to another, so also it carries the repulsion and attraction for electrons. The directions of these forces are called **lines of electric flux**. But as electrons move they cause a twistingor screwing effect on space, setting up a **magnetic flux** rotating around their path. This is traditionally measured in webers.

If the current is made to go in a circle, as in a coil, the magnetic flux passes through the middle and back round the outside. Every turn of the coil carries the current, so making more flux and producing a strong field.The flux in the middle by overcrowding gets even stronger, and shoots out along the axis to form magnetic poles.

The greater the current and number of turns, the stronger the field. Reversing the current reverses the flux, and North and South change places.

Magnetic flux causes **magnetic attraction**, physical force pulling towards each other, objects **carrying current** in the same direction or rotation; and **repulsion** between objects carrying current in opposite directions or rotations. When like poles face each other, currents and fluxes are opposed. They repel. But when North faces South, they attract.

Orbiting and spinning electrons turn atoms into tiny electro-magnets. They generally neutralise each other by different orientations and reverse spins. But in some materials, like iron, nickel and cobalt, they can be regimented to polarise in the same direction. In a magnetic field they draw the flux through them, becoming **conductors of magnetic flux**. Physically they are pulled to positions of best advantage, such as bridging gaps between N and S poles. An iron core inside a solenoid turns it into a far more powerful **electro-magnet**.

After the outside flux is switched off, the orientations remain, leaving it still magnetised, though weaker. Steel conserves this **remanent flux** so well that it can be made into **permanent magnets**. **Tape recorders** orientate atoms this way, that way, to make permanent magnetic patterns of sounds. video, or any other kind of signal.

An increase of current causes the magnetic flux to brush outwards like a cat's fur standing on end. and a decrease to bring it down again. This swishing action is just as real as when the magnet itself is moved like a paint brush with its flux for bristles. When flux brushes across another conductor, it tends to drive a current along it. This is **induction**. How much drive **(electro-motive force)** for how much swish **(rate of change of flux-density)**, is traditionally measured in henrys.

At close quarters, two coils wrapped on the same iron core, can **transform** power from one "voltage" to another by induction, even sufficient to supply the national grid. On the other hand, flux-swishing radiates at the speed of light, and can be picked up at vast distances. This is **electromagnetic radiation**. It includes not only radio. radar, and TV, but also radiant heaty light, ultraviolet, x-rays, etc. In fact. all we know about themostdistant galaxy we have yet found was transmitted by the pranks of the electrons in its neens of stars (thousands of millions), about one neenaYear ago (five thousand million)!

Some electrons break clean away or are shot away from atoms, and travel through space, often at extremely high velocities. This is **beta radiation**. Apart fro m their momentum, they are drawn by electric flux to more positive regions, and when they plunge into a magnetic field, they see it as a sort of twisted space. Without losing any linear velocity or kinetic energy, they begin to circle around the lines of flux. This could be just a bending of the path, a complete loop-the-loop or a corkscrew path, depending on Yclocity, angle and field strength. That is how pictures are made in TV tubes.

The Units

The force between two parallel conductors each carrying a current of 1 amp and placed one metre apart is 2x 10^{-7} newtons for each metre of length.

If they are placed at 1 Grafut apart it is 2 x 10^{-7} newtons for each Grafut of length. That is 4·0↊ $_9$Mag. For half an amp, the force per Grafut is 1·026 $_9$Mag, and for 0·49572 amp it is 1 $_9$Mag per Grafut exactly. So:

Unit of Current, 1 KUR (Kr) = 0·495 722 069 amp. Virtually half an amp.

6 hesiKur = **0.996** 097 9 microamp. Virtually 1 microamp.

Just as 1 watt divided by 1 amp = 1 volt, so 1Pov divided by 1 Kur gives the unit of potential:

Unit of potential, 1 PEL (Pl) = 1 Pv/Kr = 871·260 799 7,volt
(Etymology: Potential ELectric, also Latin PELlere - to drive)

1 triniPel = 0·504 20 volt. Virtually half a volt.
The 1½ volt batteries are 3 triniPel, The lead-acid 2 volt cells are 4 triniPel. A twelve volt car battery is 2 duniPel.
The fact that these units are so close te the traditional, makes it quite easy to convert readings from existing meters.

Unit of Resistance, 1 OG (Og,) = 1 Pl/Kr = 1757·559 033 ohm.
(Etymology: GO spelt backwards)

1 triniOg = 1·017 105 922 Ohm. Virtually 1 Ohm.
The ohm is a low resistance. Kilohms and megohms are common practice.

Unit of QUantity ELectrical. 1 QUEL (Ql) = 1Kur x 1 Tim= 0·086 062 859 15 Coulomb.

1 zenaQuel = **1·032** 754 310 Coulomb
The Quel = 2·↊↊46 zenquedra (*10^{14}) electrons. The electron's charge is 4·1691 zenqueniQuel ($_{15}$Ql), that is 1·602 189x 10^{-19} Coulomb.
Battery capacity is usually quoted in amp-hours. lamp-hour= 3600 amp-seconds or coulombs. Since 1 amp = 2 Kur:
1 amp-hour = 2 KurHours or quedraQuels (2 ^{4}Ql)

Capacitors

A thin layer of non-conducting material sandwiched between two metallic plates (or foils) is a capacitor. When a battery is connected across it, current cannot pass through, so there is a pile-up of electrons on one plate, giving it a negative charge, and a shortage on the other, making it positive. The capacitor is charged. The more "electricity" it takes to charge it to the potential of the battery, the greater its capacity.

Traditionally measured in farads, that is coulombs per volt. In TGM: Quel/Pel

Unit of Capacitance, 1 KAP (Kp) = 1 Q1/P1 = 98·779 675 59 μF. Virtually 100 μF.
The farad is enormously large. Microfarads and picofarads are incommon use. So the Kap is a step in the right direction.

As the charge on the capacitor grows, it slows down the incoming current. Charging starts with a rush, then peters off to a trickle. Resistance of the circuit also has a braking effect. Ohms x farads = seconds (time), and.in TGM Ogs x Kaps = Tims. This is called the " **time factor** of the circuit. Theoretically, the time to fully charge if current remained at initial rush. In practice, the time to reach 0·770 (0·632) of full charge. (That mysterious number = (1 -e^{-1}))

Examples.

1) A room is lit by four *18 duniPov (60 watt) lamps, and heated by a 6·8 Pov (3 kilowatt) heater. The mains supply is *340 triniPel (240 volt). What is the current when: a) the four lights only are on, b) the heater only, and c) all on? What is the resistance of: d) one lamp, e) the heater?

a) 4 x 0·18/0·340 Pv/Pl = **2 Kur** | 4 x 60/240 W/V = **1 amp**
b) 6·8/0·340 Pv/Pl1 = ***20 Kur** | 3000/240 W/V = **12·5 amp**
c) 2 + 20 = ***22 Kur** | 1 + 12·5 = **13·5 amp**
d) 0·340/0·6 Pl/Kr = **0·68 Og** | 240/0·25 V/A = **960 ohm**
e) 0·340/20 Pl/Kr = **0·018 Og** | 240/12·5 V/A = **19·2 ohm**

2) A car battery is 2 duniPel (12 volt) and has a capacity of *64 KurHour (38 A-hr). The dipped headlights are 0·106 Pv (37·5 W) each. Two sidelights, two tail lights. and two number-plate lights are 0·02 Pv (6 W) each. The car is left with the dipped headlight switch on. How long before the battery becomes flat?

Total Povage: 2x0·106+6x0·02 = 0;31Pv | Total wattage: 2x37·5+6x6 = 111 W
Current: 31/2 2Pv/2Pl = 16·6 Kr | 111/12 W/V = 9·25 amp
Time: 64/16·6 KrHr/Kr = **4·14 Hour**. | 38/9·25 A-hr/A = **4·108 hour**.

3) A 4 zeniKap capacitor (8 microfarad) is connected in series with a*60 Og resistance(0·5 Mohm) across a *200 triniPel (200 volt) d.c. supply. Calculate, a) the time constant, b) the initial charging current, c) time taken for the potential across the capacitor to grow to *180 3Pl (160 V), and d) the potential across the capacitor, and the current, at *20 Tim (4 sec) after connection to the supply.

a) Time constant T=RC
*60 x 0·4 OgKap = ***20 Tim** | $0{\cdot}5 \times 10^{6} \times 8 \times 10^{-6}$ohm-farad = **4 seconds**
b) Initial current I = V/R
0;200/60 Pl/Og = **0·004**Kr | $200/(0{\cdot}5 \times 10^{6})$ V/ohm = **400 μA**
c) $v = V(1- e^{-t/T})$
*180 $_3$Pl = 200 $_3$Pl$(1 - e^{-t/20})$ | 160 V = 200 V$(l- e^{-t/4})$
So $e^{-t/20}$ = (200- 180)/200 = 0·2 | $e^{-t/4}$ = (200- 160)/200 = 0·2
ln 0·2 = -1·96 = -t/20 | ln 0·2 = -1.61 = -t/4
So time t = **37 Tim** | t = **6·44 seconds**
(**ln,** the natural logarithm, is found by tables, slide rule or calculator)
d) $e^{-t/T} = e^{-20/20}$ = 1/e = 0·45 | $e^{-4/4}$ = 1/e = 0·368
So v = 0·200 x 0·77 = **132 triniPel** | v = 200 x 0·632 = 126·4 volt
i = $Ie^{-t/T}$ = 0·004x 0·45 = **158 $_5$Kr** | i = 400 x 0·368 = **147 microamps**.

Magnetism

The driving force of magnetic flux is current at right-angles. If current is straight, flux rotates around it. For straight flux, current must rotate, as in a long coil called a solenoid.

So, **unit of Magneto-Motive Force (MMF)** is:

1 KURN (Kn) = 1 Kur x 1 Turn = 0·496 ampere-turn. Virtually a half.

The **Unit of Magnetic Field Strength** (symbol H) is:

1 MAGRA (Mgr) = 1 Kn/Gf = 1·677 AT/m

(Etymology: MAgnetising GRAdient)

The "per Grafut" refers to length along the flux.

That is the electrical input. The magnetic output is measured by the force of attraction.

A force of 1 Mag per Grafut is exerted on a conductor carrying 1Kur, when it is in a flux density of 1 Flenz, that is, 1 Flum per Surf.

Unit of FLux Magnetic, 1 FLUM (Fm) = 151·26 webers

Unit of FLux dENSity (symbol B), **1 FLENZ (Fz)** = 1730·1 Wb/m^2

1 triniFlenz = 1·001 Wb/m^2

What density of flux for a given field strength depends on the **permeability** μ of the substance. μ =

B/H:

Unit of perMEABility, 1 MEAB (Mb) = 1 Fz/Mgr = 1032 Wb/ATm

The definition of the Kur gave a force of only 1 neeniMag between two conductors 1 Gf apart and each carrying 1 Kur. That is a flux density of 1 neeniFlenz.

Taking one of these currents, the circle of flux that passes through the other has a circumference of 2π Gf, giving H = 1/2π Kn/Gf.

This gives the **Permeability of Free Space** as (1 neeniFlenz)/(1/2π Magra) = = 2π neeniMeab

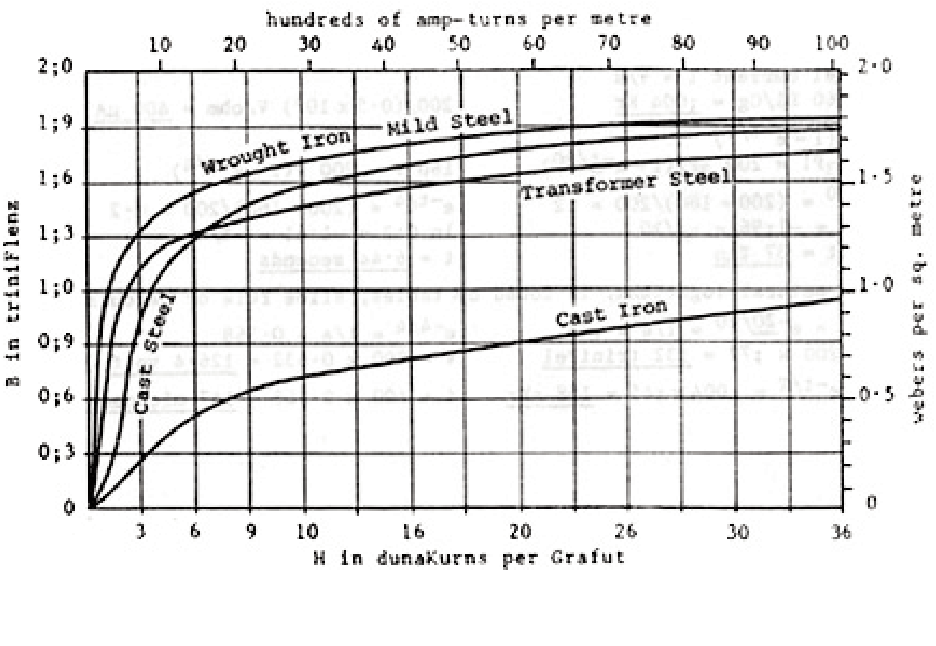
Permeability of magnetic materials varies for different magnetising gradients and is usually presented in the form of a graph of B against H:

Example 4. An electro-magnet of mild steel has a mean effective length of 2 Gf (60 cm). The poles confront each other across a gap 2 duniGf long (4 mm). Through the gap is a conductor carrying 4 Kur(2 amp) and engaging with flux for a length of 1·6 zeniGf (3·7 cm). The magnetising coil has *1000 turns (1700).

What is the magnetising current required to produce a force of 9·5 quedriMag (0·12 newton) on the conductor?

Force F on the conductor = BLI. B flux density, L length of flux engagement, and I current in conductor. So flux density B = F/LI.

B = $_4$9·5/(0;16x4) = 1·6↊ $_3$Flenz	B = 0·12N/(0·037mx2A) = 1·62 Wb/m^2
Permeability of air = 2π $_9$Meab	4π x 10^{-7} Wb/AT m
So magnetising gradient for airgap =	
$_3$1·6↊/$_9$6·35 = 3 ^{5}Magra	1·62/(4πx 10^{-7}) = 1 289 000 AT/m
MMF for gap:~	
^{5}3 x $_2$2 = ^{3}6 i.e. *6000 Kurn	1 289 000 x 0·004 m = 5157 AT
Magnetising gradient for core (from graph of B/H):	
for l·6↊ $_3$Fz = Ɛ00 Kn/Gf	for 1·62 Wb/m^2 = 3000 AT/m
MMF for core:	
*Ɛ00 x 2 Gf = 1↊00 Kurn	3000 x 0·6m = 1800 AT
Total MMF:- *6000 + 1↊00 = 7↊00 Kn	5157 + 1800 6957 AT



Magnetising current I_m:

*7↊00Kn/1000T = **7;↊ Kur** 6957 AT/m/ 1700 T = **4·1 Amp**

Relative Permeability of a material (symbol μ_r) is its **Absolute Permeability** (symbol μ. As already met. in Meabs) divided by the **Permeability of Free Space** (symbol μ_0). It is a plain number.

For the core in Example 4:

Absolute permeability μ = 1·6↊ $_3$Fz /↋00 Mgr =1·85 $_6$Meab (5·4.'x 10^{-4} Wb/ATm)

Relative permeability μ_r = 1·85 $_6$Mb /2π $_9$Mb =330 (43,= *2↋↊)

(Since data given were not strict equivalents, decimal was higher on BM curve, a little less steep giving a little lower permeability)

PERMEABILITY OF FREE SPACE IS THE EIGHTH REALITY OF TGM

Inductance

That which impels electrons is called Electro-Motive Force (EMF). n TGM measured in Pels. traditionally in volts.

When a conductor moves sideways across a magnetic flux an emf is induced in it.

The formula is E = BLv.

So if the flux density B is 1 Flenz, the length L of conductor actually in the field is 1 Grafut, and the velocity of the conductor is 1 Vlos, then an emf E of 1 Pel is induced while the movement lasts.

Since the Flenz is 1 Flum per Surf, and the Vlos is 1 Grafut per Tim, it is obvious that in this case the conductor cuts across 1 Flum per Tim. This is called rate of change of flux, and the formula is written:

$E = d\phi/dt$

So a change of 1 Flum per Tim generates 1 Pel.

Instead of the conductor moving, it can remain stationary while the flux is made to brush across it, which amounts to the same thing. There are two ways: 1) by moving the magnet or solenoid producing the flux, 2) if the flux is due to a controllable current, increasing it causes the flux to bristle outwards, and on decrease, to close in. The generation of an emf in one conductor byvarying the current in another is called **mutual inductance**. The change also induces a current in its own conductor. This is called **self inductance.**

Their formulae are:

Mutual	Self
$E = -M(dI/dt)$	$E = -L(dI/dt)$

How much emf for what change of current depends on the permeability of space or core through which the flux flows, the closeness of the conductors and their numbers of turns. That is what the M and L stand for. Each system has its own particular value of inductance.

Unit of Inductance.

A system which generates 1 Pel for a current change of 1 Kur per Tim, has an inductance of **1 GEN (Gn)** = 305·131 777 henry.

Example 5.

An iron core has *200 (300) turns wound on it. A change of current from 4 to 5;6 Kur (2 to 2·8 amp) increases the flux from 4 to 4·5 hesiFlum (200 to 220 μWb).

What is the inductance?

Let change occur during 1 Tim. Let change occur during 1 sec.

Then $d\phi/dt$ = 5 seviFlum per Tim Then $d\phi/dt$ = 20 μWb per sec.

inducing 5 seviPel in each turn.

Total emf = 5x *200 = ↊00 seviPel.

Inductance= emf/(dI/dt) =

↊ queniPel/(1·5 Kr/Tm) =

6·8 queniGen

inducing 20 μV in each turn.

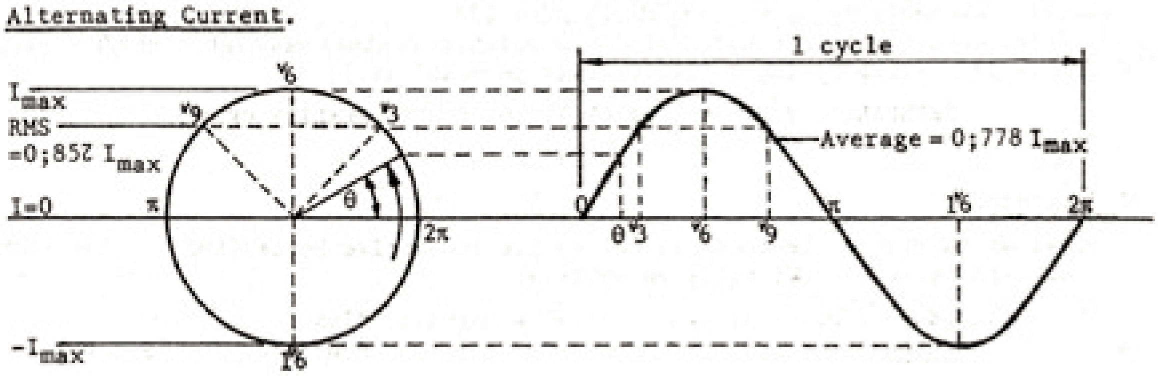
Total emf = 20 x 300 = 6000 μV

Inductance = emf/(dI/dt) =

6 mV/(0·8 A/s) =

7·5 millihenry

Current cannot rise for ever. To exploit inductance (and many other things) alternating current is used.



Generated by rotating machinery the magnitude rises and falls like a spot on a steadily turning wheel. It is called sinusoidal fo r it is always proportional to the sine of the angle turned to at each moment.

In the second half-cycle the current flows in the opposite direction to the first half. which makes the average for the whole cycle zero. The average for the first half comes out at 2/π times I_{max}, = 0·778 I_{max} (0·637), and f or the second, ditto with a minus sign. it is not a flow of electrons that goes along the wire, but a vibration causing localised oscillating currents at each point passed.

In practice a current is measured by the work it can do, which is proportional to its square. And squares of negative numbers are positive.So the square root of the mean of the current squared is used as nominal current. It Is known as **Root Mean Square** (RMS). For a sine wave it is equal to half the square root of two, times I_{max}, which is also the sine of v3 and v9, that is 0·85↊ I_{max} (0·707). 0·86 for quickies.

RMS/Average is called the **Form Factor** = π√2/4 = 1·14 (1·111..) = ↊/9.

Peak/RMS is called **Peak Factor** = 2/√2 = √2 = 1·4↋8 (1·414), 1·5 for quickies

Example 6.

A transformer has *2600 turns (4600) in its primary winding, and *80 (100) in its secondary. An alternating current at 9 cycles per Tim (50 c/s) and having a peak value of *90 Kur (50A) is sent through the primary, giving a maximal flux of l;6 quedriFlum (0·0108 Wb).

a) What is the average rate of change of flux?

The change is from +1·6 to -1·6 $_4$Fm in half a cycle (+0·0108 to -0·0108 Wb)

3 $_4$Fm/8 $_2$Tm = **4·6 $_3$Fm/Tm** — 0·0216 Wb/0·01s = **2·16 Wb/s**

b) What is the average emf induced in the secondary?

Each turn receives an emf so total E = Ndϕ/dt

*80 x 4·6 $_3$Fm/Tm = ***300 triniPel** — 100 x 2·16 Wb/s = **216 volts**

c) What is its RMS value? (Form factor = add one nineth)

*300 + 40 = ***340 triniPel** — 216 + 24 = **240 volts**

d) What is the self-inductance of the primary?

L = -E/(dI/dt) = -Ndϕ/dt/(dI/dt) = -Ndϕ/dI.

L = -*2600 x 1·6 $_4$Fm/90 Kr = **5 $_3$Gen** — -4600 x 0·0108 Wb/50A = **0·994 henry**

e) What is the mutual inductance of the secondary in respect to the primary?

M = -*80 x 1·6 $_4$Fm/90 Kr = **1·4 $_4$Gen** — -100 x 0·0108 Wb/50A = **0·0216 henry**.

Electric Force

An alternating current applied to a capacitor hasthe deception and effect of going through it. The electrons do not pass through, but only flow in and out to charge and discharge first in one direction and then the other.

What does pass through is the **electric force** of repulsion or attraction. A surplus, i.e. negative charge on one plate repels electrons out of the opposing plate giving it a positive charge, and vice versa.

Just as materials and vacuum have a permeability for magnetic force, similarly they have a **permittivity** for electric force.

Unit of perMITtivity, 1 MIT (Mt)

= (1 Quel/Surf)/(1 Pel/Grafut) = 334·073 (coulomb/sq.m)/(volts/metre).

The numerator is the **Unit of Electric Flux Density** (symbol D):

1 QUENZ (Qz.) = 1 Quel/Surf = 0·984 381 coulombs/sq. m.   Virtually 1 to 1.

The denominator is the **Unit of Electric Field Strength** (symbol E):

1 ELGRA (Egr) = 1 Pel/Grafut = 2946·6 volts/metre.

(etymology: ELectric GRAdient)

Absolute and Relative Permittivity.

The permittivity of a material as found above and expressed in Mits, is its **absolute permittivity**, symbol e = D/E. The **absolute permittivity of free space** has the symbol e_0.. **Relative permittivity** is the absolute permittivity divided by e_0 and has the symbol e_r. *[Ed. I have used e instead of a Greek character which I don't have at the moment.]*

The electromagnetic equation of space

It is a fact of nature that the product $\mu_0 e_0$ is equal to $1/c^2$, where c stands for the velocity of light in free space.

c = 4·ƧƐ4 992 3 sevaVlos exactly (299 792·458 m/s exactly)

c^2 = 20·171 447 99 zendunaVlov (^{12}Vv) (8·987 551 787x 10^{16} m^2/s^2)

$1/c^2$ = 5·Ɛ72 Ɛ83 057 zenquedriPerVlov ($_{14}$PVv) (1·112 650 056 x 10^{-17} s^2/m^2)

Dividing this by μ_0, i.e. 2π neeni (4π x 10^{-7}) gives:

Permittivity of Free Space.

e_0 = 0·Ɛ49 061498 1 seviMit (8·854 187 818x 10^{-12} coulomb/volt-metre)

(Experiments to revise TGM, basing it on e_0 = 1 seviMit exactly, have been thrashed out, but the disadvantages far outweigh the advantages. G= 1 comes unstuck for a start.)

Example 7.

The effective area of a capacitor is 3·6 Surf (0·3 m^2) and the dielectric is mica 1·9 triniGrafut thick (0·3 nun) with a relative permittivity of 6. What is the capacity?

C = $e_0 e_r$area/thickness = 1 $_7$Mt x 6 x 3·6 Sf/1·9 $_3$Gf = $_4$10 i.e. **1 triniKap**

C = 8·9 x 10^{-12} C/Vmx 6 x 0·3 m^2 = 5·34 x 10^{-8} = **0·05μF**

Had relative permittivity been quoted as 6;0 instead of plain 6, it would have been proper to use 0·Ɛ5 for e_0 and give answer to two significant places.

Exercises.

1) The element in an electric iron has a resistance of *68 $_3$0G (80 ohms) and is connected to a *340 $_3$Pl (240 V) supply. a) What is the current? (Kur = Pel/Og) b) What power is consumed? (Pov= KurPel), c) How much heat is produced in 1 $_1$Hr (5 min.)? (Werg= PovTim), d)How much electrical energy is con-

sumed in one hour?

2) A capacitor has a working area of 0·24 Sf (0·019 m^2). Its dielectric has a relative permittivity of 6, and is 7 $_4$Gf thick (0·1 mm). a) What is its capacity? (C = $\epsilon_0\epsilon_r$area/thickness. Use ϵ_0 = 1 $_7$Mt (8·9x 10^{-12} SI units)).

If connected in series with a resistor of 6 Og (10 kilohms) across a supply of *16 3Pl (9 V), b) what is the time constant? (T = RC), c) what is the initial charging current? (I_{max}= E/R), d) what is the current at the instant when time elapsed equals the time constant? (i = $I_{max}(1-e^{-t/T})$, i and t are instant current and time, e^{-1} = 0·45 (0·368)).

3) A 2 duniPel (12 volt) car battery has a capacity of *64 KurHour (38 amp-hour). The car. with battery fully charged, is put away in the garage but with the interior roof light left on. The resistance of the roof lamp is *20 $_3$Og (24 ohms). How long before the battery is flat? (Kur = Pel/Og).

4) A wrought iron core has a mean cross-sectional area of 8 $_3$Sf (0·000 4m^2 and an effective length of 9 $_1$Gf (22 cm). The air gap between its poles is 1 $_2$Gf (2 mm). If the supply current is to be 0·6 Kr (0·25 A), how many turnsmust be wound on it to give a flux of *12 $_6$Fm (0·0007 Wb)?

(Method: First find flux density B, same for both core and air gap. Divide this by μ_0. and multiply by length of air gap tofind Kurns required for air gap. From the graph find H for wrought iron correspon-ding to your flux density. Multiplied by length of core gives Kurns for core. Divide total Kurns by current, and you're there).

5) A transformer has *1400 (1600) turns in the primary winding and *100 (100) in the secondary.

a) What is the turns ratio? (N_2/N_1)

b) If the primary is supplied with an alternating current at *340 $_3$Pl(240 V) RMS, what will be the RMS emf in the secondary? (Multiply by turns ratio).

c) What will be the peak values of emfs in primary and secondary?

(Peak factor = √2 = 1·50 (1·41).

d) If a current of 4 Kur (2A) is drawn from the secondary, what current will the primary draw? (Multiply by turns ratio).

Chapter 7: Counting Particles

For some applications it is more convenient to reckon amount of substance by number of items, rather than by weight or volume, especially in chemistry and nuclear physics.

Common salt (posh name: sodium chloride) has just one sodium atom to each atom of chlorine. But by weight it has onezen elv (23) parts sodium to every twozen elv and a half (35·5) parts chlorine, because of the different weights of the atoms.

So for ratio simplicity, weights of chemicals have been reckoned in **gram-atoms** that is, the same number of grams as their atomic weight numbers. Or in **gram-molecules**, as per molecular weights, when counting molecules. So:-

1 gram-atom sodium (23 g) + 1 gram-atom chlorine (35·5 g) makes 1 gram-molecule of salt (23+ 35·5 = 58·5 g).

All gram-atoms stand for the same number of atoms, and all gram-molecules, for that same number of molecules. In today's metric, SI, that amount is called a "mole". Here is its full definition:-

A mole is that amount of substance which contains as many elementary particles as there are atoms in twelve grams of carbon-12. (Though SI is based on the kilogram, the mole is based on the gram).

Q; But how many is "as many"?

A: About 6·022 04 x 10^{23}, called Avogadro's Number N_o (or N_A or L).

TGM Unit of Amount

The Maz is about 25 kg, so a dozen Maz contains about twenty five thousand times as many as twelve grams. The TGM mole is therefore that much bigger, and is given the name MOLZ, pronounced "mollz", abbrev. Mlz.

A MOLZ is that amount of substance which contains as many elementary particles as there are atoms in zen Maz of carbon-zen (=25 850·356 moles)

Carbon-zen, abbr. C*10, is, of course, only the dozenal translation of the decimal "carbon-12", and refers to the very same isotope.

1 quedriMolz ($_4$Mlz) = 1·2466 moles, about one and a quarter. Ratio 5 : 4.

The actual Avogadro's number is, of course, also bigger:-

***Avogadro's Number (TGM)** the **EM** (abbr. M) = 1·439Ƶ4dunduna (1·55672x 10^{28}).

(Remember dunduna? Means *10^{22}, a "1" followed by twozen two noughts)

(*This was given the symbol N_z in the earlier edition (bottom of page 11))

Prefixes

emi- Divided by Em, abbr. m-
The **emiMaz** (mMz) is 1 Maz/Em
=8·9Ƶ86 1 $_{23}$Mz
= the **unified atomic mass unit m_u**

ema-(or em-) Multiplied by Em, abbr. M-
1 gram/N_o
= 1·66057x10^{-27} kg

There is no reason why "m_u" should not also be used in TGM, for its value is the same. But "mMz" shows it in perspective to the system as a whole, and can cancel out to plain "Mz" when an Em turns up.

Note: emi, the reciprocal of M, = $_{23}$8·9Ƶ86 (6·42376x10-^{29})

Example 1

A Molz of sodium carbonate means I Em of Na_2CO_3 molecules. This Consists of 2M at of sodium, 1M atoms of carbon, and 3M atoms of oxygen.

To find the mass we use mMz to cancel M by m:-

2M x lƐ mNz + lMx 10 mMz + 3M x 14 mMz = 3Ƶ Mz + 10 Mz + 40 Mz = 8Ƶ Mz.

(Of course there is no need to write such things out in full every time).

The sodium atom has Ɛ electrons, carbon has 6, and oxygen has 8. So the Molz of sodium carbonate has 2MxƐ + 6M + 3Mx8 = *44M electrons. For each electron there is a proton in a nucleus, so there are 44M protons.

Standard Gas Volume 1AVOLZ(Avz is the volume of 1 Mlz of a gas at STP (ice point and atmospheric pressure) = 10Ɛ41·Ƶ Volm = 578·2844 m^3

which is within I pg (0·7%) of *11 trinaVolm. So for practical conversions:-

1 Avz = 11 ^{3}Vm, 2 Avz = 22 ^{3}Vm, etc.

In a gas, molecules are free to dart around like a swarm of gnats. Thehigher the temperature, the more active, causing increase in volume, or, if contained, increase in pressure. This is summarised by the universal gas formula-

RT = pV

T. (temperature) must, of course, be in absolute units, Calgs (kelvins in metric), and R is the constant ratio between T and pV (pressure, volume).

Gas Constant R = 1·ƐƵ77 58 PmVm/Cg per Molz = 8·3143 J/K per mole.

This is well within 1 pg of a simple 2. (Prem x Volm, by the way, = Werg).

It can be handy to write R as R_z to mean "in TGM units". The $_z$ is only a marker. Though numerically different, R = R2 when units are reckoned in.

A quick (and very accurate) way to find R_zT from degrees C is:-

1) Knock 2 degrees off thermometer reading,
2) convert to dunaCalgs ,
3) multiply by 2.

Example 2 Find R_zT for 20°C.

18°C= 180 d° = *130 d°. Add *1700, = 41830 ^{2}Cg, x 2 Wg/CgM, = *3460 ^{2}Wg/M.

By the exact method the figure is 3463.

At ice point, 1 Molz of gas occupies lAvolz at 1 Atmoz (2Ɛ Pm). At 0·6 Atz it occupies 2 Avz, at 3 Atz, 0·4 Avz, and so on.

Example 3 2 Mlz of gas occupy 2 AVz. The pressure is 2Ɛ Pm. Using the formula RT = pV, and assuming R = 2 PmVm/CgMlz andAvz= 1·1 quedraVolm, calculate the temperature in Calgs.

2M1z x RT= 2Ɛ Pm x 2·2 ^{4}Vm. So T =

$$\frac{2Ɛ \times 2{\cdot}2\ Pm\ {}^4Vm}{2\ Mlz\ (2PmVm/CgMlz)} = \frac{28 \times 1{\cdot}1}{2}\ {}^4Cg$$

= 31·Ɛ/2 ^{4}Cg = 16Ɛ6 ^{2} Cg

Compare this with the exact ice point, 16Ɛ7·6 ^{2}Cg.

Try it in metric: 2 moles occupy 4·483 x 10^{-2} m^3. The pressure is 101·325 N/m^2. R = 8·3143 J/Kmol.

Solutions

It is established metric practice to speak of a "1M" or "2M" or "lM", etc. solution. By "1M" is meant 1 mole of solute in 1 dm3 of solution. So it is not a pure mole to mole ratio. 1 mole of water occupies 0·018dm^3. A 1M aqueous solution is 1 mole solute in 55·555. .moles of solution. Apart from the "18" (molecular weight of water), a 1M solution contains a hidden factor of a thousand.

"Molarity" is used to describe "mol/dm^3", "molality" for "mol/kg".

Corresponding TGM is:**Unit of Molvity, 1 MOLV (Mlv)** = 1 Mlz/Vm = 1000 mol/litre = 999·972 mol/dm^3

Unit of Molmity 1 MOLM (Mlm) = 1 Mlz/Mz = 1000 mol/kg

In TGM there is no such thing as a 1M, half-M or any other-M solution. The SI 1M solution becomes a 2 quedri solution:-

2 quedriMolv (2 $_4$Mlv) = 0·09644 mol/dm^3

Electrolysis

In solution many molecules become ions, they borrow or loan electrons. If incorporated in an electric circuit so that a potential stands across the solution, positive ions drift to the cathode, and negative ions to the anode. The release of the charge at the electrode causes chemical changes such as release of gas molecules, removal of metal from the anode and/or the deposition of metal (electroplating) on the cathode.

The number of atoms released or deposited is equal to the number of electrons that have passed any chosen point of the circuit, divided by the valency of the atom. A valency of 2 takes 2 electrons to release 1 atom. $n_a = n_e/v$

If I is current and t time, then number of electrons n_e= It/e, e being the charge of an electron. Let a be relative atomic mass of the atom, mass released or deposited then is:

m = (It/e)(a/v) emiMaz or Atomic Mass Units.

For TGM Maz divide this by Em For grams divide by N_o

Example 4 A current of Ɛ Kr (5·5 A) flowed through a solution of copper sulphate for 1 hour. How much copper was deposited, a)number of atoms, b) in Maz, c) in grams? Atomic mass copper= *53·67 (63·55), valency 2. e = 4·16 $_{15}$Ql = 1·6 x 10^{-19}C.

Number of electrons, It/e:-

Ɛ Kr x 1 Tm /$_{15}$4·16 Q1 ^{19}2·8	5·5 A x 3600s/(1·6x10^{-19}) = 1·24x10^{23}
So number of copper atoms deposited is:-	
^{19}2·8/2 = ^{19}1·4 Answer a)	1·24 x 10^{23}/2 = 0·62'x10^{23} Answer a)
Multiply by atomic mass of copper:-	
^{1Ƶ}53·67/9 = ^{1Ƶ}7·09 mMz or m_u	63·55 x 0·62x 10^{23} = 3·94x$10^{24}$$m_u$
Divide by Em:-	Divide by No:-
^{1Ƶ}7·09 /^{22}1·44 = 5·23 $_4$Mz Answerb	3·94 x 10^{24}/6·02x10^{23}.= 6·54g Answer b

Acidity.

The voltaic cell, commonly called "battery" uses electrolysis in reverse to make current from chemical action. A special kind is used to measure acidity:-

The meter measures the potential difference (Pels, volts) between the two electrodes. It is proportional to the concentration of hydrogen ions in the solution, so it is graduated to give direct pH readings.

pH means "minus the logarithm (base ten) of the hydrogen ion concentration (in mols per dm^3)". in symbols, pH = $-\log_{ten}$ [H^+}. Beware positive mantissæ with negative characteristics, the pH of 2 x ten^{-7} is 6·699, not 7·301.

The meter is first set by putting the electrodes in a buffer solution of known pH, and adjusting the reading.

Even in pure water some molecules ionise: H_2O —›H^+ + OH^-, until there are

1·004 x 10^{-7}moles of H^+ in every litre at 25°C. As there are also the same number of OH^- ions, 1·004 x 10^{-7} is the point of neutrality, neither acidic nor basic,and pH7= neutral.

But the litre is the volume of a kilogram of water, while the mole is based on the gram, so pH values contain a hidden factor of ten to the third. Adding 3 to the pH cures this, putting it in terms of kmols per dm^3, the same ratio as Molvs, and universal for any project having unit mass equal to unit volume of water no matter what counting base. Dozenising this pH+3, gives the TCM measure of acidity:-

Scale of Acidity, in **decHyons (dH)** = $-\log_{↊}$ (H^+concentration in Mlv) = pH + 3

making it easy to convert existing data into terms meaningful to TGM. "$\log_{↊}$", of course, means log to base ten in dozenal numeration.

Finding logs and antilogs to whatever bare, even common logs, always involves tables, slide rules, calculators or computers. Though it may be pretty to supersede this in due course by a scale on dozenal common logs, there is no advantage at the present time.

Examples: Water: pH7 = dH↊, Vinegar pH4, = dH7. Phenol pH9·886 = dH10·↊77 (12·886)

Example 5: pH of a solution is 2·15 i.e. dH 5·15 = dH 5;1↊. Find its arithmetic value.

Decimal, by calculator or computer: $10^{-5·15}$ = 7·0795 x 10^{-6} kmol/dm^3

For those who have tamed these gadgets to give dozenal answers:

$↊^{-5;1↊}$ = $_5$1·918 i.e. 1·918 queniMolv

By slide rule: Decimal, set 1 scale C to 10 on LL3. 5·15 on C is now beyond the LL scales, so from 1·15 on C read 0·071 on LL03 and multiply by 10^{-4}.

Dozenal slide rule: set 1 scale C to ↊ on LL3. From 5·1↊ on C read on LL03 1·9 x 10^{-5}

Tables, decimal: -5·15 = $\bar{6}$·85. Antilog = 7·0795 x 10^{-6}

-4·937 is the dozenal common log of this acidity. For those wishing to pursue this line of development,

Tables, dozenal: Not having tables of logs to base ↊, we must multiply by zlg ↊

to convert to common dozlogs:-	n	zlg	zlgzlg
		(-)5·1↊	0·7↋02
	↊	0·↋153	$\bar{1}$·↋770
		(-)4·937--	0·7672
	$_5$1·90-.	--$\bar{5}$·285	

a scale of **dozHyons (zH)** = - zlg(H^+ conc. in Mlv) is suggested.

dozHyons (zH) = decHyons (dH) x 0·↋153 = (pH+3) x 0·9266

THE MASS OF THE ATOM OF CARBON-ZEN IS THE NINTH REALITY OF TOM

Exercises

1) What is the mass of one molecule of ethanol, C_2H_6O a) in unified atomic mass units, b) in emiMaz, c) in Maz, d) in kg. (Atomic wts. : H=1, C=*10, O=*14. Use: 8·Ƨ $_{23}$Mz and 1·7 x 10^{-27}kg for a.m.u.)

2) What is the mass of a) 2 Molz of ethanol in Maz, b) 2 moles in kg?

3) How many electrons in a) 1 Molz of ethanol in terms of M, b) in full

c) 1 mole? (H has 1 electron, C 6, and O 8).

4) A quantity of gas occupies 8·8 trinaVolm (1·5x10^{-2} m^3). If the temperature is zero decigrees (0°C) and the pressure is one and a half atmospheres, how many Molz (moles) does the quantity represent? (Metric V_o= 2·24 x 10m^3).

5) What is the R_zT in exercise 4? b) Divide your answer by 2Ɛ PM, then by 1·6. What do you notice about these two results?

6) What is the decimal RT in exercise 4? (R = 8·3 J K^{-1} mol^{-1})

7) *4Ƨ $_4$Mz (58 gm) of sodium chloride, NaClI, is dissolved in water to make 3 $_1$Vm (5 dm^3)of solution. What is the Molvity (molarity)? (Atomic wts.: Na 1Ɛ (23), Cl 2Ɛ (35)).

8) A metal plate of total area 0·35 Sf (250 cm^2) is chromium-plated by a current of 1 zenaKur (6 A) for 1 hour.

a) What is the mass deposited (in Maz and grams)? b) What thickness is the deposit?

(Chromium: atomic weight *44 (52), valency 6, density 7·2 Denz (7·2 g/cm^3)

Mass deposited = It(a/v)/(M.e) (Dec: It(a/v)/(N_oe)

NOTE: N_oe is the metric unit, the **faraday (F)** = 9·6487x10^4 C. The TGM counterpart is, of course, the **Emelectron (Me)** = 5·7499 ^{9}Ql. (a/v)/Me or (a/v)/F is the **electro-chemical equivalent** For chromium: *44/(6x^{9}5·7499)= 1·666 $_9$Mz/Ql

dec: 52/(6x96487) = 0·08982 mg/C

9) The hydrogen ion concentration of a solution is 2 hesiMolv (6·7x10^{-4}mol/dm^3) What is the acidity in a) dozHyon (zH) (Dozenal common log, with "-" removed),

b) decHyon (dH) (zH divided by zlg Ƨ (0·Ɛ153)),

c) pH (Decimalise dH and subtract 3)

Chapter 8: Reckoning by Ratios

Doubling-up and Halving-down

These are some of the commonest sums we ever do, yet we have many ways of expressing them, some rather enigmatical.

In paper sizes we speak of “demi, folio, quarto, octavo,” etc. In music,a note of twice the frequency is said to be “an octave up”. “Two octaves up” means four times the frequency. In electronics and acoustics, “a gain of three decibels” is a way of saying that the output signal has twice the power of the input. “Plus 12dB” means onezen-four times as strong. In photography, a film of sensitivity 15 DIN is twice as sensitive as 12 DIN. These “plus threes” that mean “twice as” come from the fact that the decimal logarithm of two is 0.30103.

TGM calls a double a “DOUBLE”. “2 DOUBLES” means four times, “3 DOUBLES” means e,ght times, and so on. “An octave up” is a DOUBLE of frequency, Again of 3 W, a DOUBLE of power, and so on.

If we go up three octaves and then down one, we finish at two octaves up. 3 DOUBLES minus 1 DOUBLE = 2 DOUBLES. So a MINUS DOUBLE is a halving-down. If a full paper sheet is called size 0, then “demi” or “folio” is -1. “quarto” is -2, “octavo” -3, etc.

2 + 2 = 4 doubles, means x 4 x 4 = x 14

1 + 1 = 2 doubles, means x 2 x 2 = x 4

So ½ + ½ = 1, means xn xn = x2 (n=√2)

A HALF-DOUBLE means multiplied by the square root of two, a QUARTER-DOUBLE, by the fourth root, an EIGHTH OF A DOUBLE, by the eighth root, and a THIRD OF A DOUBLE by the cube root, etc.

What we are now doing is composing logarithms to base two. Expressed in dozenal numeration they form a unique system for handling ratios, with simplicities not found in any other system. The music keyboard was caused to have twelve semitones to the octave by this.

zeniDOUBLES

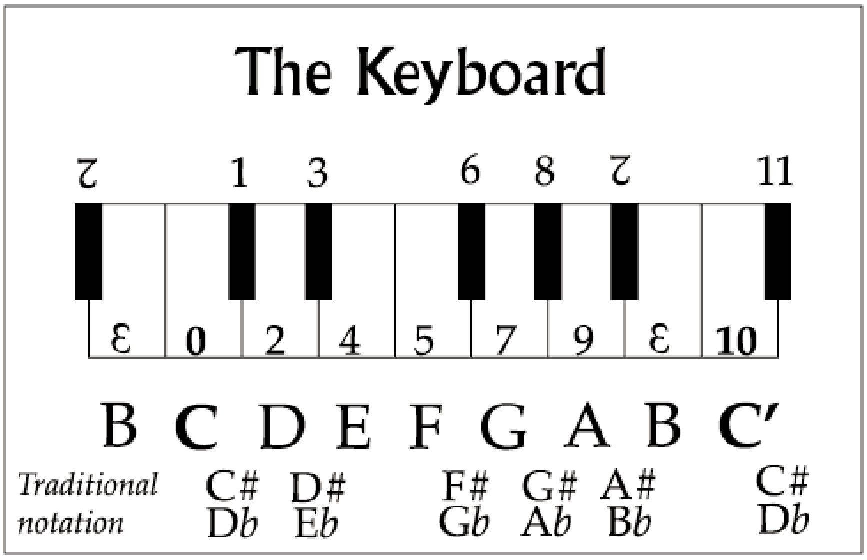
Putting these fractions into zenimals, not only gives 0·2, 0·3, 0·4, 0·6 for the sixth, fourth, cube- and square-roots, but also 0·7 (seventh power of twelfth root) stands for a ratio extremely close to 3/2 or 1·6.. 0·5 (fifth power of twelfth root) is extremely close to 4/3 or 1·4. The double of 3/2 is 3, which doubled is 6, leading on to zen. Taking their DUBLOGs to be 1·7, 2·7 and 3·7 is far more accurate than assuming the decimal log of 2 to be -3.

Dub-logs	Note Nos.	Value dozenal (decimal)	Comments	*Ratios	Error P.g. (%)
0·0	78	1·0000 (1·0000)			
0·1	79	1·0869 (1·0595)	Zenth root of two	15/14	-0·50 (-0·29)
0·2	7↊	1·1577 (1·1225)	Sixth root of two	9/8	-0·40 (-0·23)
0·3	7↋	1·232↋ (1·1892)	Fourth root of two	6/5	-1·37 (-0·91)
0·4	80	1·3152 (1·2599)	Cube root of two	5/4	+1·18 (+0·79)
0·5	81	1·4027 (1·3348)	4/3 almost exact		+0·1↋ (+0·11)
0·6	82	1·4↋79 (1·4142)	Square root of two	7/5	+1·55 (+1·01)
0·7	83	1·5↋91 (1·4983)	3/2 almost exact		-0;1↋ (-0·11)
0·8	84	1·7070 (1·5874)	Cube root of four	8/5	-1·18 (-0·79)
0·9	85	1·8222 (1·6818)	Fourth root of eight	5/3	+1·37 (+0·90)
0·↊	86	1·946↋ (1·7818)		7/4	+2·69 (+1·78)
0·↋	87	1·↊7↊0 (1·8877)		13/8	+0·↋9 (+0·68)
1·0	88	2·0000 (2·0000)		2/1 exact	

(Note numbers: see following music section)

A practical example of zeniDoubles is the standard musical keyboard. The pattern repeats itself every

MUSIC



dozen keys.

Pick a key (say the first of two blacks). Th e same key in the next pattern to the right is traditionally said to be “an octave higher”. What that means in sound effect (which is what music is all about) is , that it makes a sound vibrating at twice the frequency of the other.

Music has CONCORDS and DISCORDS. Concords are when the vibration frequencies are in a simple ratio, say 2: 1 3 : 2 4 : 3 etc. They drop into step af ter every few, sounding as though they merge.

These ratios are required no matter which key we happen to start with. There is no arithmetical way this can be done to perfection, for it calls for successive powers of each ratio, none of which comes to an exact multiple of two. An infinite number of keys per "octave" would still be not enough!

The answer has to be a compromise: some number which multiplied successively by itself gives answers very close to the simple ratios, and eventually reaches two exactly. That number is the twelfth root of two.

Tuning instruments to zeniDouble values has been standard practice since the days of Johann Sebastian Bach. It is called "Equal Temperament". From one note to the next is traditionally called a "semitone", but the only sensible definition of a "whole tone" yet found is: "two semitones" i.e. not to the next key, but the next but one.

The musical significance, i.e. in sound, is that the frequencies are in the ratio: one to the twefth root of two. In other words:

A "semitone" is a zeniDouble of frequency.

The most concise and precise definition found anywhere.

The errors shown in the doubles table are the "out-of-tuneness" of the zeniDouble values from the exact ratios. 1 : 1 and 2 : 1 are, of course, exact. Next come 3 :2 and 4 :3, so close that only professional ears can discern them while listening for "slow beats" with the two notes held together f or at least one zenaTim (couple of seconds). Next, ratios with a 5 are more out of tune but not objectionably so, but ratios with a 7 are the first discords. The merging sounds a little uneasy.

In TGM all notes are numbered serially in dozenal, the units figure telling which particular note as in the diagram, the zens figure, which "octave or ZENADE (like "decade" but dozenal) it is in.

Note 60 (sixzen) is the main reference note, traditionally called "Middle C. Note 50 is the "C an octave below", Note 70 an "octave above". Note 78 is the "A flat or C sharp in the second octave up from Middle C, much quicker to say, "Note sevenzen eight", meaning Note 8 in zenade 7.

Exercise 1. What are the note Nos. of the following?:-(Get units figure from diagram). a) B below Middle C. b) F sharp above Middle C. c) E*b* below Middle C, d) E in the second octave down from Middle C. e) B*b* in the 3rd 8ve up from Middle C.

To find the frequency ratio of any two notes, subtract the lower note No. from the higher. Look up the value for the units figure (zeniDoubles) in the table then double it the number of times shown by the dozens figure, e.g. :

Note 68 -Note 53 = *15. 0·5 in table gives 1·4027. Dozens figure is 1, so double once. Answer: 2·8052.

2·8 = 8/3, so the higher note does 8 vibrations for each 3 of the lower, with a slight out-of-tuneness.

Note 87 -Note 65 = *22. 0·2 in table gives 1·1577. Multiply by 4, gives 4·5↊64. This is near to 4·6 which is nine vibrations to two.

Pitch.

This is absolute frequency, in vibrations per Tim (or per second, called herz).

Unit of Frequency, 1 FREQ (Fq) = 1 cycle per Tim = 5·76 Hz.

(The Freq was called CIM (Cm) in the earlier edition).

Two pianos can sound beautifully in tune when played separately, but could sound horribly out of tune when played together. This is because they are not tuned to the same pitch. Note 60 on piano A is not giving the same frequency as Note 60 on piano B, and all its other notes are relatively "out" with their counterparts on piano B. An international standard of pitch has therefore been agreed to which all instruments should be tuned.

International Standard Pitch. A above Middle C= 440 herz or cycles per second.

In TGM: Note 69 = 64·48 Freq resulting in Note 78 = 100·252↊ Fq'

A note tuned to exactly *100 Freq is only 0·252Ꮗ of a vibration behind in every Tim. The reciprocal, 4·Ɛ13, is the period of the out-of-tuneness beat, when played with the standard A*b.* They must be held at least twice this, i.e. Ꮗ Tim (1·7 sec) to be noticed. The period is twice as long for Note 6 8, a zenade lower, and next to the International Standard A. Even experts can detect the error only by careful testing. So:

TGM Standard Pitch: Note 78 = *100 Freq. Virtually= 440 Hz for A above Middle C.

Absolute pitch of Notes 78 to 88 can now be read direct from the table of zeniDoubles (col 2). Multiply the values in col 3 by *100, e.g.

Note 81 vibrates at 140·27

Note 85 vibrates at 182·22

For Note 8Ꮗ read Note 7Ꮗ, at 115·77, and double it, = 22Ɛ·32

For Note 73 read Note 83, at 15Ɛ;91, and divide by two, = 8Ɛ·Ꮗ6

Exercise 2. Find the absolute frequency in Freqs of: a) Note 86, b) Note 6 8, c) Note 58, d) Note 48, e) Note 9Ꮗ, f) Note 49, g) Note 56.

Other examples of using Note Nos.:

Violin strings are tuned to Notes 57, 62, 69, and 74.

The compass of a flute is from Note 60 to about Note 90.

A B*b* clarinet is a MINUS-TWO CLARINET. Each note sounds 2 zeniDoubles lower thanwhat the player's fingers read on the music. An A clarinet is a MINUS-THREE.

Sharps, flats, key signatures, and many other things can be discarded as useless complications.

Dublogs.

It is now clear that Doubles and zeniDoubles are a system of logarithms to base two. Expressed in dozenal numeration they have advantages not found in any other method, and we give them the special name:

DUBLOG: A logarithm to base two expressed in dozenal numeration.

The main tables give dublogs only for numbers 1 to *10. other numbers are treated as a number for the table multiplied by a power of zen. Dlg *400, for instance, is 2·0000 + 7·2058 = 9·2058. Dlg 0·04 is 2;0000-7·2058 = -5·2058.

Those are STRAIGHT DUBLOGS. For some applications it is convenient to use only positive mantisswa(the fraction part), and put the minus sign, when used, over the characteristic. -5·2058 then becomes $\bar{6}$·9Ɛ64 meaning -6 +0·9Ɛ64.

The ablog (or antilog, in traditional terms) gives you the ordinary number. Dlg 4 = 2, ablog 2 = 4.

Exercises.

1. Find the dublogs of: a) l·24, b) 2·489 c) 4·94, d) 0·72, e) 0·37, f) Ɛ·798, g) 2;ᏃƐ5, h) 5;9ᏃᏃ.
2. Find the ablogs of: a) l·3473, b) 0·9365, c) l·Ꮗ724, d) 1·4Ɛ92.

3. Find the mixed dublogs and straight dublogs of: a) 0·09, b) 3·2 x $*10^7$, c) 4Ɛ0, d) 9·46 queni, e) two and a quarter hes.

4. Find the dublogs of: a) 4π/3, b) $3{\cdot}76^2$, c)√8, d) $473{\cdot}5^{1/4}$.

Paper Sizes.

Metric has an A and a B series. In both, all sheets have their longer side equal to the shorter multiplied by the square root of two. When folded or cut across into two equal parts, the resulting sheets are still of the same proportion since √2/2 = 1/√2.

The B series derives from a full sheet, B0, 1 m x √2 m. Halving down in the way just mentioned gives two B1 size. Doing it again gives four B2. Then eight B3, and so on. The size numbers are logarithms to base two with the minus sign removed.

In the A series AO is one square metre. The longer side is the fourth root of two, 1·189m, the shorter = l/fourth root of two, 0·841m. Now 1·189mdivided by 4 = 0·297m. The Grafut happens to be 0·2956m. So: **TGM Paper Sizes are virtually the same as the metric international A and B sizes**.

Trimming the edges to bring them to TGM standard is a pointless waste of time.

Metric is only 0·8 pg (0·5%) up on TGM, which for the present can be classed as "manufacturing tolerance".

B4 size has an area of 1 Sf. A4 has a length of l Gf. A3 has a width of 1 Gf.

The square root of two is 1·4↋79, the fourth root of two 1·233, and 1/fourth root 0·↊1109 ... A slight rounding off puts them to 1·5, 1·234 and 0·↊1respectively. 1·234 x 0·↊1 = 0·↋↋↋74.... Here is the full list:

TGM Paper Sizes

Dozenal (trimmed)		Metric		Dozenal (trimmed)		Metric	
Grafut	Surf	mm	m^2	Grafut	Surf	mm	m^2
A0 2·↊ x 4·0	↋·4	841 x 1189	1	B0 3·44 x 4·914	14	1000 x 1414	1.414
A1 2·0 x 2·↊	5·8	594 x 841	0.5	B1 2·468 x 3·44	8	707 x 1000	0·707
A2 1·5 x 2·0	2·↊	420 x 594	0.25	B2 1·82 x 2·468	4	500 x 707	0·3535
A3 1·0 x 1·5	1·5	297 x 420	0.125	B3 1·234 x 1·82	2	353 x 500	0·1765
A4 0·86 x 1·0	0·86	210 x 297	0.0625	B4 0·↊1 x 1·234	1	250 x 353	0·0883
A5 0·6 x 0·86	0·43	148 x 210	0.03125	BS 0·718 x 0·↊1	0·6	176 x 250	0·0440
A6 0·43 x 0·6	0·216	105 x 148	0.01562	B6 0·506 x 0·718	0·3	125 x 176	0·0220
A7 0·3 x 0·43	0·109	74 x 105	0.00781	B7 0·36↊ x 0·506	0·16	88 x 125-	0·0110
A8 0·216 x 0·3	0·0646	52 x 74	0.003906	B8 0·263 x 0·36↊	0·09	62 x 88	0·005456
A9 0·16 x 0·216	0·0323	37x 52	0.001953	B9 0·195 x 0·263	0·046	44 x 62	0·002728
A↊ 0·109 x 0·16	0·01716	26 x 37	0.000976	B↊ 0·1316 x·0195	0·023	31 x 44	0·001364

Example.

The format of a booklet is four dozen pages, six by eight and a half zeniGrafut (148 x210 mm). Four pages were printed on each face of a sheet. a) What is the sheet size in Gf (mm)? b) its code? c) How many sheets required? d) The paper substance is 6 $_4$Mz/Sf (85g/m^2). What is the weight of one gross (150) booklets?

a) Sheet size = (2 x 0·6) by (2 x 0·86) (2 x 148) by (2 x 210)

b) A3 =1 Gf by 1·5 Gf (297 mm by 420 mm)

c) 2 faces x 4 pages = 8 per sheet. So number of sheets = *40/8 = 6 per booklet

d) Total area =(6x1·5)Sf x *100=860Sf. (6x0·125) m^2 x 150 = 112·5 m^2

Weight *860 x6 $_4$Mz = 4·3 zeniMaz. 112·5 x 0·085 kg = 9·5625 kg.

Exercises

1. An A4 ·sheet is folded in three to go in a long envelope 4·5x 8·↊ zeniGrafut (109x218 mm). a) What are the dimensions of the folded sheet in $_1$Gf (mm)? b) What is its area in $_2$Sf (cm^2)?

2. Another A4 sheet is folded in four to go in an envelope 6·7x 4·8 zeniGrafut (162x 114 mm). a) Folded dimensions in $_1$Gf (mm)? b) Area in $_2$Sf (cm^2)?

Number e, the Complex Double.

One and one make two. If something grows to add its own value, i.e. **double itself**, in zen years, its average rate of growth is *10 per gross.

If the increase due is added each year and the next is calculated from the increased value, it **more than doubles** in zen years to 2·7434. Adding 1 pg each calendar month or zeniYear, it grows to 2·8610. 0·1pg each duniYear (2·6 days) comes out to 2·873Ƨ, and so on.

Things growing naturally usually do so proportionally to their size at every passing moment (the "dt" seen in formulæ), for which the answer is the number e, = 2·875 236 069 821 Ƨ... an unending fractional in every counting base. The decimal value is 2·718 281 828 459 ....

It is called the "base of natural logarithms" and causes awkward expressions like "$e^{1-L/R}$" to appear in formulm. Nature really is complex.

Prefix:- DUB- (D-) = "Doubles of", e.g. 3 DubFreq = 3 "octaves", 4 DPv= Pv x *14.

Chapter 9: Light

When we say "c = the velocity of light", "light" i s loosely used to mean electromagnetic radiation. Of the vast range of frequencies in this phenomenon less than one double, from about wavelength *4000 $_9$Gf (4000 Å) to about *7800 $_9$Gf (7600 Å)are able to incite vision, which is what light is all about.

How much light for how much power, the visibility factor, varies from colour to colour. Highest in the yellowy-green at wavelength *5730 $_9$Gf (5550 Å), f or which it is 679·6 lumen/watt. This is 1·179597 lumen per queniPov. So:

Unit of Light Power, 1 Lypov (Lp) = luminous flux from 1 queniPov of radiation at wavelength *5730 $_9$Gf (5550Å) = 1·179597 lumen.

Visibility factor for this wavelength is one Lypov per queniPov. Outside the light-greens and yellows it quickly falls. Orange and medium green are down to 0·9 (0·75). Cherry to scarlet, and the deeper greens, run from 0·6 (0·5) down to 0·2 (0·17). Crimson and blue are about 0·1 (0·08). Violet and deep crimson run right down from about 0·02 (0·014) taking over sixzen times the power of pea-green to give the same strength of vision.

Strength of illumination is how much light per unit area:

Unit of Light Density, .1 Lyde Ld) = 1 Lp/Sf = 13·492 148 5 lum/m^2

(Lyde was called Ludenz in earlier edition) = 1· 253 461 6 lum/ft^2

1 $_1$Ld = 1·1243457 lum/m^2

Light radiating from one point falls off as the square of the distance. If Lydes. are multiplied by the square of the distance, the answer is the luminous intensity of the source:

Unit of Light Intensity, 1 QuaraLyde (QLd) = 1 Lypov per steradian

(This was called Luprad in earler edition) = 1·179597 candela

Finally, to cause vision, light has to enter an eye. Through the pupil and lens to form an image on the retina, which then sends signals to the brain. If the light is too bright, the iris closes down the **aperture** making the pupil look smaller. Like a camera, it adjusts the **exposure** to suit the **sensitivity** of the retina (or film).

Effective value of aperture depends on size in proportion to the focal length of the lens. Automation is making people forget expressions like "f/16", "f/11"etc .., which mean diameter equals focal length divided by sixteen, or eleven, etc. Why eleven? Twice the diameter gives four times the area, admitting four times as much light. For a scale of exposures in doubles, f-numbers had to go in halfdoubles, each "stop" being square root two times the next. √2 x 8 = Ɛ·4.

Human eyes are about 1 zeniGrafut (2 dozen mm, a small inch)in diameter. The main lens-to-retina distance is a little less. Pupil diameters most of the time are from 3 to 1 duniGrafut (6 to 2 mm) . So aperture usually is from f/4 to f/Ɛ.

Illumination on retina (or film)f called "exposure", is equal to that on the subject divided by the square of the f-number. (Fall-of f due to distance is cancelled by subject to image area ratio). In photography it is multiplied by the time the shutter is open, measuring the quantity of light admitted.

Unit of Light Quantity, 1 Lyqlua (Lq) = 1 LpTm = 0·204 791 1 lumen-sec.

Illumination, apertures, shutter speeds, blinking. etc. all serve to bring the exposure to an optimum called "correct exposure" constant f or the particular system. The greater it is the lower the sensitivity.

Unit of Sensitivityp 1 Senz (Sz) = 1/LdTm = Sf/Lq = 0·42691 5 m^2/lum s

(This is an arithmetic unit. The earlier edition gave it a logarithmic value, not reliable). The logarithmic unit is now formed by the prefix Dub-:

DubSenz (DSz) = a Double of sensitivity = +3 in DIN, Scheiner, BSO.

Many worked examples point to: 0 DSz = ASA 16, 13 DIN, 24 Sch°, 23 BS°

In practice many things take part: angle of lighting, B & W or colour, spectrum distribution, etc. Straightforward examples were chosen, and treated to some form of the formula

X = 2F - E - S

X being Dlg exposure (Tims), F D1g f No., E D1g illumination (Lydes), S DubSenz

Exercise . A lamp has an intensity of *Ɛ0 QuaraLyde(140 candela). What is the illumination in Lydes (lum/m^2) at 6 Gf (2m)?

Stars.

Traditional "magnitudes" measure faintnesst each "magnitude" being 2.512 times fainter than the next lower (brighter). This magical number is the fifth root of a hundred. -5 mags means 100 times brighter.

As seen in the sky brightness is only apparent. A very bright star at a very great distance can appear very faint. Sofor physical comparison. absolute magni tudes are calculated, being the magnitudes they would have, if **all** stars were viewed from a uniform distance, traditionally ten parsecs.

In TGM parsecs and such religious worship of the number 5 are inappropriate. Instead, we measure **brightness** in Doubles, each DubBrite (DBt) being twice the brightness of the next fainter. 0 DBt is on the verge of visibility to the naked eye. A minus sign indicates need of binoculars or stronger optical aids.

If 0 DBt were exactly equal to trad. mag. 6, the absolute brightness of our Sun, viewed from a distance of **1 lightyear**, would be Ɛ·676 DBt. We start the other way round, call absolute brightness "brilliance", and put:

The BRILLIANCE of our SUN. i.e. its brightness viewed from a distance of one LIGHTYEAR. is *10 DUBBRIL.

It follows that Ɛ DBl is half the Sun's brilliance, *11 DBl twice as brilliant, 10·7 one-and-a-half times, 11·7 three times, 13·7 zen times, and so on.

This puts the zero of DubBrites for apparent brightness to trad. mag. 6·24, still close to the eye/binocular fringe.

At normal distance, 1 Astru, Sun's brightness is 37·Ɛ (trad. -26·7).

THE LIGHT-GIVING SUN IS THE LAST REALITY OF TGM

bringing us full circle to the cause of night and day, the first reality.

Exercise 3. Find the dublog of the fifth root of a hundred(nearest zenidouble). To convert mags. to dubBrites subtract 6·241 dozenise and multiply by the dublog you found in 3. Change the sign + to - or vice versa.

4. a) Sirius is mag. -1·46. What is its brightness in dubBrites?

b) How many times brighter is the Sun? (Sun = 37·Ɛ DBt).(Abg of DBt differenco c) Sirius is 9 lightyears away. What is its brilliance in DBls?(DBt+2Dlg Lys). d) How many times more brilliant than the Sun is it in reality?(Sun= *10 DBl).

Chapter ↊: Getting to Grips

Until data is readily available in TGM, experimenting with the system is handicapped by having to translate it from traditional measures. As this involves not only a change of units but also a change of number base, it can sometimes be very awkward indeed.

The most satisfactory long-term solution is to have additional TGM scales engraved on household and bathroom scales, measuring jugs, barometers, rulers. tape measures, voltmeters. etc, etc, so that things can be weighed and measured directly in TGM. It is not really difficult, even for amateurs, to do this from the data in this booklet. The compiler of TGM has done so to most of his everyday gadgetry.

The resulting dual scales also work like the read-off conversion scales (see later), which are fairly quick and accurate enough for many purposes. Handy approximations are also found in the remarks column of the digital conversion tables (see later).

These tables are very comprehensive, covering not only the primary units but also many, many derived units for all sorts of applications. This is to save you the trouble of having to multiply several of them together every time. Dublogs of the factors are included, so you can go straight into that system.

The factors are given at length to ensure accuracy and consistency in all translations between systems, now and in the future. There is no implication as to the degree of accuracy the units themselves have as yet been experimentally established. The figures were obtained by computer working to onezen three placesq and by formulæ most direct to the primary Tim. Vlos, Gee and Denz. Cut them off to suit your purpose. If you start from three significant figures in decimal, there is no point going on to four or more in dozenal.

Put them in your computer together with powers of zen up to zen to the zenth. Then you can easily get values for the millis, kilos, and quedra, akis, etc of the units.

A handy little Basic loop to "spell out" a number into dozenal, is:

```
10 Let n = (n-INT n)*12: PRINT n
20 GO TO 10
```

How to incorporate it and escape when you have enough digits, depends on your program and type of computer.

The decimal number should first be divided by the highest power of twelve below it. This gives an answer between one and twelve. Usually, if the decimal order is ten to the i. then divide by twelve to the i. sometimes i-1 or i+l).

Note the dozenal exponent. It is the order of the dozenal answer, hes for 6, duna for 2. queni for -5, etc. Note the integers of successive displays:

Example: 5029·75 (in the thousands so divide by twelve to the third (1728)

lst	display	2·910734	Write	2
2nd	display	10·928819	Write	↊
3rd	display	11·145833	Write	↋
4th	display	1·7499999	Write	1
Sth	display	8·9999999	Write	0·9

Answer 5029·75 = *2↊↋1·9

To "spell" dozenal numbers into the computer, start at the right hand and work to the left, using this routine:

```
10 LET n=0
20 INPUT "Next digit from right', d
30 If d < 0 then stop
40 LET n=(n+d)/12 : PRINT n
50 GO TO 20
```

(Line 30 stops the program when you inout a negative number; otherwise it would run and run ...)

Example: 0·02↊9Ɛ

1st input	11	display 0·91666
2nd input	9	display 0·82638
3rd input	10	display 0·902199
4th input	2	display 0·2418499
5th input	0	display 0·02015416
6th input	-1	to finish

Answer *0·02↊9Ɛ = 0·020154

Elaborate these to make the computer do the one by one write out and read in so that you can handle complete numbers. LET n = PI and see it appear in dozenal on the screen. For the cosine of 1 zeniPi, LET n=COS 150, or, in radian mode, LET n=COS(PI/12), and so on.

It is possible to build on this a Basic program to do simple arithmetic in dozenal, but it works slow (for computers) and is continually using the decimal form of floating point routines. The inside process is: dozenal to decimal to binary to decimal to dozenal.

Wanted: A dozenist computer-programmer skilled in machine code, who can write dozenal analogies of the decimal floating point routines found in present-day computers. Then we can have our computers calculating in real “dozenal mode”.

Whether by computer, dublogs or read-off scales, once into dozenal, think dozenal. Numbers like “thi-irty-two” (i.e. three tens plus two) ‘ “forty-seven” etc. do not exist in dozenal. All those indoctrinated thoughts youhave learned that use such words, including multiplication and addition tables, have to be tucked away into the decimal archives of your mind. Gone is the thought, “four eights are thirty-two”· instead, we have, “four eights are twozen-eight” and so on.

*0·99999.. is only nine elevenths. It is *0·ƐƐƐƐƐƐ ... that is virtually one.

At first glance numbers in dozenal look like just another string of digits, as with decimal. But it is good practice from time to time when looking at a digit, to ask yourself how many of it go to make up a one, a two or a three in the column to its left. If the digit is 2 the answer is, of course, six, for 3 four, for 4 three, for 6 two. 8s are three to each 2 on the left, 9s four to each 3. This can become intuitive after a little practice. Digits become meaningful instead of mere symbols. Just out of curiosity try the same thing in decimal, and see how you get lumbered with “two-and-a-half”s, “three -and-a-third”s, and that prime number five!

Quedra is a little over twice the ten thousand. So every four places to the left of the dozenal point means roughly a doubling up on the value the same digits would have, read as a decimal number. Every four noughts to the right of of the point (minus 1) before a zenimal begins, means roughly a halving down of the value if read as a decimal. Grouping dozenal digits in fours thus helps us to understand, for the meaning of numbers is their values.

TGM may not be the final answer to dozenal metrology, but it provides a realistic foundation for colat-ing further data, and defining units, traditional, or even of rival projects. No need for everyone to plough back to the decimal metric every time through very high order dec-doz conversions. If a length unit is y Gf, figures for the lightyear, radius of electron, Astronomical Unit, etc. are quickly obtained dividing the TGM figures by y.

TGM is here to serve. Use it as you will

Footnote, May 2011

A set of conversion tables which followed this page in the original edition are published separate-ly. This revised pdf edition has been produced for use by members of the DSGB, the DSA and the online Dozenal Forum.