METRICATION

AN INTRODUCTION TO SI UNITS

BY

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History

Why metrication? This has not been, as many people think, something that has been foisted on an unwilling public by the Government. To do credit to all concerned, it was the Confederation of British Industries who first approached the Government and said that the great majority of British industry was in favour of 'going metric'; they said that the time was ripe for the Government to make a statement and to give a general time-table for carrying out the change.

Over 60 per cent of our exports go to metric countries, and over 80 per cent of the world's population uses the metric system—small wonder that the CBI was keen on the idea. The moment of decision was the 24th May, 1965, when the then President of the Board of Trade made a statement in the House of Commons in which he gave a period of ten years as the time to carry through the change. We were on our way.

Without going into the politics—the pros and cons of converting to the metric system—it should be said that the author is convinced that it was a sound decision. The purpose of this artcile is to look into the mechanics of the changeover—or perhaps more strictly one main aspect of it—and to see what it actually means to us as engineers.

An essential catalyst in this process is the British Standards Institution (BSI). They have been given the job, like John the Baptist, of making clear the path ahead of industry. They have undertaken to re-issue all their standards in metric form so that industry can use the new metric standards from the outset. The BSI have also been directed to base all British metric standards on international agreement, so that any new British metric standard will virtually be an English edition of the standard issued by the two main international bodies, the ISO and the IEC—which stand for the 'International Standards Organization' and the 'International Electrotechnical Commission'.

The BSI are thus the focal point of the whole business. Very properly they put first things first and started with the raw materials of engineering. They concentrated on such things as steel sheet and bars, piping, fasteners (that is, bolts and nuts), and so on. They are now tackling the manufactured products and reckon already to have cleared all the really important standards.

There is one side effect that must be mentioned. As each industry reviews the range of its products and decides what sizes it shall produce in the metric range, a golden opportunity will present itself for severely pruning unnecessary sizes which had grown up perhaps over years and even decades. It gives a chance of making a fresh start; of reviewing the whole range of products and eliminating unnecessary intermediate sizes. One of the greatest hopes is that industry will grasp this chance with both hands and streamline the ranges of its products.

Which Metric System?

So the decision was made to go metric. The BSI was all geared up to revise some 3000 standards over a period of, perhaps, three years. But of which metric system are we speaking?

We in this country who are used to working in the imperial system have been accustomed to looking across at the Continent with their kilogrammes and metres and litres and to thinking of them as *the* metric system. But it is not generally realized that there are at least three metric systems from which to choose.

Most of us at school—at least those of the author's generation—were taught the 'CGS' system. This was based on the centimetre for length, the gramme for mass and the second for time. These were the so-called 'base units' from which many others grew—for example, the dyne for force, the erg for work, and so on (the so-called 'derived units'). The CGS was a complete system of units with which all scientific and engineering calculations could be made. Unfortunately those units, although perfectly satisfactory for scientific use, were far too small for practical engineering purposes. The gramme was tiny; the centimetre was impractically small except, perhaps, for buying ribbon; only the second was really useful. So there came the 'MKS', or metre-kilogramme-second system. Here the three base units were of a more practical size for engineers' use. And, as will be shown later, the derived units come out very nicely indeed. For some time now the MKS system has been taught in schools and universities in preference to the CGS.

Both the CGS and the MKS systems however cover only mechanical units—length, mass, time, and derived units like velocity, acceleration, force, energy, power, and so on. An Italian gentleman named Giorgi had the bright idea of adding an electrical unit to the three mechanical base ones, so extending their use into a much wider field. He could have chosen any electrical unit, and all the others could then be derived from that and the mechanical ones. He chose the ampere, and the system became known as the 'MKSA'—metre-kilogramme-second-ampere—or simply the 'Giorgi' system.

This development struck a responsive chord throughout the technical world and, together with three other base units, the 'kelvin' as the unit of temperature the 'candela' as the unit of luminous intensity and the 'mole' as the unit for amount of substance in physical chemistry, it is now being adopted internationally by nearly all the principal engineering countries—notably by France, Germany, Russia and Japan. It is known as the 'Système International d'Unités' or 'SI': this is just the 'with-it' name of the further-expanded MKSA or Giorgi system.

Most Continental countries have already passed laws to make the SI form of metric system the only legal one. Very naturally this country has decided to go straight from Imperial to the SI system rather than to take two bites at the cherry—first to go to CGS or MKS and then, like France and Germany, to go on to SI. This was a very sensible decision. It is of interest that the CEI and the principal Engineering Institutions such as the IEE and the IMechE have decided that all engineering examinations will be conducted in SI units from 1972 onwards—that is, for students starting their studies from 1969.

The Immediate Problem

So there are at least three metric systems in existence—the CGS, the MKS and the SI. This country is committed to go to the SI, where it will join all the other principal metric countries (but not yet the U.S.A. and Canada). As far as the immediate changes are concerned—that is, in the dimensions of products—this distinction is not very important. It does not matter much whether the metre or the centimetre is the base unit of length—we can use multiples or sub-multiples as we wish—the kilometre or the millimetre. So also for mass: the gramme or kilogramme can be used at will. So when it comes to redesigning a product, any of the metric systems will do. But here one very important point must be stressed.

In converting from inches to, say, millimetres, the conversion factor is 25·4. So an article one foot long will come out at 304·8 mm. Now it is definitely not the intention that the same product shall be made to the old gauges and jigs and just be sold with the equivalent metric dimensions on it—like a packet of biscuits which is labelled '½ lb (227 gr)'. It is the intention that the metric dimensions shall, wherever possible, be rounded off—your foot length becomes 300 mm exactly, and that means new drawings, gauges, jigs and all the apparatus of production. The 6 ft 6 in. door will become 2 metres exactly. The equivalent metric product will in general not be interchangeable with its imperial counterpart, so there will be storekeeping, marking and cataloguing problems. As previously mentioned, the immediate impact of the changeover will be to affect the physical dimensions and weights.

With factory-made products there will be the associated problems of drawings, machine tools, jigs, gauges and so on. These are extremely important, but not difficult. To sum up this aspect, the changeover in the factory will require attention to:—

Drawings
Machine Tools
Hand Tools
Jigs and Gauges
Storekeeping
Cataloguing and Sales
Training
Handbooks
Spare Gear

These are the immediate problems. Others have written about them in much greater detail—about how they are being tackled one by one. But here the main interest is the metric system— that is the SI system—and how it affects engineers, and in particular design engineers. It is the engineers who will really have to use the new units to the full—in their designs, in the construction and finally in the performance of the product, be it a pocket transistor receiver or propulsion machinery. So it is these units rather than mere dimensions that will be the main concern of this article.

The SI Units

In the SI system the base units—that is, the units from which all the others are derived—are seven in number. They are:—

length	— the metre	(m)	MKS mechanical units
mass	— the kilogramme	(kg)	
time	— the second	(s)	
current	— the ampere	(A)	— electrical
temperature	— the kelvin	(K)	— thermodynamic
luminous intensity	— the candela	(cd)	— illumination
amount of substance	— the mole	(mol)	— physical chemistry

It is on these seven that hang all the Law and the Prophets. From them can be derived many others, for example:—

velocity	— metre/second	(m/s)
acceleration	— metre/second^2	(m/s^2)
momentum	— mass × velocity	($kg.m/s$)
kinetic energy	— mass × velocity^2	($kg.m^2/s^2$)
density	— mass/volume	(kg/m^3)
elect. charge	— current × time	($A.s$)
mom. of inertia	— mass × length^2	($kg.m^2$)
mass flow rate	— mass ÷ time	(kg/s)
vol. flow rate	— volume ÷ time	(m^3/s)

to name just a few.

Going back to the base units and looking closer at the first three, which are the same as the original MKS units, it will be noticed that one important one, 'force', is missing. Newton's Second Law of Motion in its simplest form is expressed as Force equals Mass times Acceleration—$F = m.a.$ See FIG. 1.

That is, unit force is that which will give unit acceleration to a unit mass. In SI the unit of acceleration is 1 m/s^2 and the unit of mass is 1 kg. So the unit of force is 1 $kg.m/s^2$. This is a bit of a mouthful, so it is called the 'newton' in honour of the man whose law it expresses. It is perhaps the newton that gives

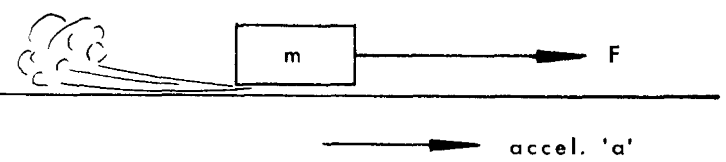


FIG. 1—NEWTON'S SECOND LAW OF MOTION

most trouble to anyone new to the SI system. As amatter of interest, it also existed in the old MKS system, but hardly anyone noticed it. It is to the MKS and SI systems what the 'dyne' was to the CGS or what the 'poundal' was to the Imperial system.

	F		m		a
SI or MKS:	newton	=	kg	×	m/s^2
CGS:	dyne	=	g	×	cm/s^2
Imperial:	poundal	=	lb	×	ft/s^2

The newton frightens most people because, like the old poundal, it was not used much, and it is difficult to imagine it in the mind, whereas one could always picture a pound weight. In the past we preferred to measure force in 'pounds' and so confused it with mass, which was also measured in pounds. It is important therefore to distinguish very carefully between force, mass and weight.

For most people the only practical way of measuring mass is by weighing it. When your wife buys a pound of potatoes, what she really wants is a collection of potatoes whose mass is one pound. So the greengrocer puts it on the scales, where the pull of the earth's gravity on the potatoes is compared with its pull on a standard lump of iron, or where it deflects a calibrated spring, and he says that it 'weighs' one pound. What he means of course is that the earth is pulling it with the same force as it pulls a certain standard mass of one pound.

If this transaction had taken place on the moon and the potatoes had been weighed on a balance, they would still balance against a lump marked '1 lb', but they would in fact weigh far less—indeed only about $2\frac{1}{2}$ oz. If on the moon they had been weighed on an earth-made spring scales, the pound mass of potatoes would only have registered $2\frac{1}{2}$ oz on the scale; yet there would have been just as many potatoes as before—quite enough for your moon dinner. So the mass has remained unaltered, but the weight—that is, the gravity force pulling on it—has been reduced by a factor of 6, depending on the local 'g'.

So mass and weight are *not* the same thing. One is an unalterable property of the substance; the other is a function not only of the mass but also of the local gravity. On the moon it is only a 1/6 fraction; in space it would be zero, that is weightless. But it certainly would not be massless, as you would find out if you bumped your head against an orbiting bag of potatoes. Thus, as weight varies with location, it is dangerous to use weight units to define force. The only safe way is to define unit force by Newton's Second Law: that is, by its ability to accelerate a unit mass by a unit acceleration. When that unit mass is the base SI unit (the kilogramme) and the acceleration is the derived SI unit (the metre/second^2), then the unit of force so defined is the newton. The same newton will accelerate the unit mass by exactly the same amount whether on earth or on the moon or, indeed, in space.

In the past attempts were made to distinguish between true mass (measured in pounds) and the gravitational force on that mass by calling the latter 'pounds-force' and abbreviating it to 'lbf'; in fact, all current textbooks and British Standards use this expression. Similarly on the Continent, the unit of mass is the kilogramme and the unit of force is the 'kilogramme-force', abbreviated to 'kgf'. This is the current practice in most metric countries although gradually changing over to SI units concurrently with the UK. Both pounds-force and kilogrammes-force depend on gravity and are therefore not universal. Only the SI unit, the newton, is truly universal, and that is why it is replacing the kilogramme-force, even in metric countries.

So mass and force are two totally different things and are measured by two totally different units. Weight is simply the pull of gravity on mass; it is therefore a pure force and should be measured in newtons only. It depends on both the mass being pulled and on the local gravity, thus:—

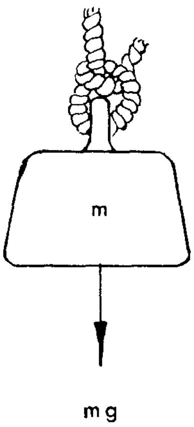


FIG. 2—WEIGHT = m g. NEWTONS

If the mass is one kilogramme, then the weight is g newtons. On the earth g equals 9·81 m/s^2, so the weight on earth of a mass of one kilogramme is 9·81 newtons; on the moon it would be about 1·5 newtons and in free space nothing at all. But the *mass* remains 1 kg throughout.

'g'

You will remember from your schooldays the eternal trouble of 'leaving out the g'. This was because in wrongly using mass units for force, g was brought in where it should not have been, and the necessity to take it out again was often forgotten.

Consider again Newton's Second Law; it can be written in two ways:—

$$F = m.a \quad \text{(absolute units)}$$

$$\frac{F}{W} = \frac{a}{g} \quad \text{(schoolday error)}$$

The former is Newton's law in its absolute form as propounded by Newton himself. But most of us were not taught that; we will recognize the second expression as the form in which we first saw it. But in this second form the unit of force is different. F is not measured in poundals (the true force unit) as it should have been, but in pounds-weight which is numerically g times smaller. To get the equation to balance, the g has to be re-inserted on the right-hand side. But Newton's Second Law applies universally: not only on earth, but also on the moon and in space *and has nothing to do with g.* Therefore g should not enter into the picture.

One of the attractive features of the SI system is that, if you keep exclusively to SI units, and in particuler to the newton as the unit of force, g never appears except where gravity forces actually come into the picture. Newton's Second Law takes the upper form, where F is in newtons, m in kilogrammes and a in metres/second^2. Only if weight (as distinct from mass) is a consideration is its force written 'mg' and measured in newtons. Similarly, g does not appear in other expressions which are independent of gravity, as it did in your schooldays. For example:—

	Schooldays	*SI*
momentum:	$\frac{mv}{g}$ lb-sec	mv kg.m/s
kinetic energy	$\frac{1}{2}\frac{mv^2}{g}$ ft-lb	$\frac{1}{2}mv^2$ kg.m^2/s^2

The newton has been considered rather carefully here because it seems to be the only thing that really worries people and tends to frighten them off the SI system. How do you picture it? It has been shown that a mass of 1 kg (that is about 2¼ lb or 36 oz) has a weight (on earth) of g, or 9·81 newtons, say 10 newtons roughly. So one newton would be the weight of a mass of about 3½ oz, say the weight of an apple! The author has always found this link between the newton and the apple very useful.

The newton is important for other reasons too. Not only is it the derived unit of force in the SI system, being equivalent to 1 kg.m/s^2 (the three mechanical base units), but it also appears in dozens of other derived units which involve force. For example:—

work, energy:	newton-metre	Nm	= joule (J)
power:	work/second	Nm/s	= J/s = watt (W)
torque:	force × length	Nm	
pressure:	newton/metre^2	N/m^2	= pascal (Pa)
viscosity		Ns/m^2	

Note that some, but not all, of these derived units have their own private names: the watt and joule were certainly well established long before SI units were heard of. But one thing is common to them all, whether named or not: every derived unit has a one-to-one relationship with the units from which it was formed. There are no conversion factors which plague the life of most engineers. So long as you stick to the proper SI units, you will form only other SI units with no conversion factors whatever. Thus:—

1 newton × 1 metre = 1 joule
1 newton × 1 metre ÷ 1 second = 1 watt
(or 1 joule ÷ 1 second)
1 ampere × 1 second = 1 coulomb
1 watt ÷ 1 ampere = 1 volt
1 volt × 1 second = 1 weber

Such a system is said to be 'coherent': that is, every single unit has a simple one-to-one relationship with every other. This is one of the principal attractions of the SI system.

It will be seen that our old friends the joule and the watt are reappearing rather strongly in the new SI system. The watt is of course well used, but the joule has until now been regarded as rather an academic or text-book unit.

The CGS unit of force, the dyne, was defined as that force which would accelerate a unit mass of one gramme by a unit acceleration of one centimetre per second^2, that is, it is 1 g.cm/s^2. Going from the CGS to the MKS system, the unit of force, the newton, is defined as that force which would accelerate one kilogramme by one metre per second^2, that is, it is 1 kg.m/s^2. Now:—

Force: $1\ \text{N} = 1\ \text{kg} \times 1\ \text{m/s}^2 = 1000\text{g} \times 100\ \text{cm/s}^2$
$= 10^5\ \text{g.cm/s}^2$
$= 10^5$ dynes

Work: The SI unit is the newton-metre (Nm)
1 Nm = 100 N.cm
$= 100 \times 10^5$ dyne-cm
$= 10^7$ erg
= 1 joule (J)

Power: The SI unit is the newton-metre per sec (Nm/s)
1 Nm/s = 1 J/s
= 1 watt (W)

This shows how nicely the SI derived units fall out using already well-established existing named units.

Multiples and Sub-multiples

Any unit can of course form multiples and sub-multiples by adding the prefixes kilo-, mega-, milli-, micro-, etc., but these are not regarded as conversion factors, as their meaning is always apparent. For instance:

$$1 \text{ kilonewton} \times 1 \text{ metre} = 1 \text{ kilojoule}$$
$$(1 \text{ kN} \times 1 \text{ m}) = (1 \text{ kJ})$$

The full range of prefixes, now internationally agreed, is:—

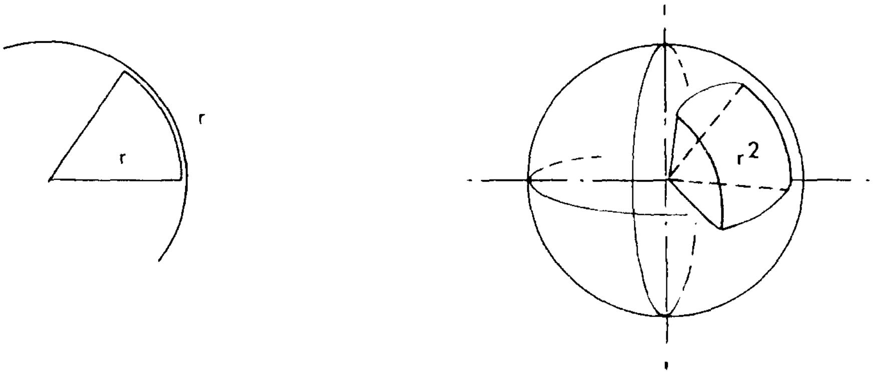
10^{12}	tera-	T
10^{9}	giga-	G
10^{6}	mega-	M
10^{3}	kilo-	k
10^{2}	hecto-	h
10^{1}	deca-	da
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f
10^{-18}	atto-	a

The uses of these prefixes will be discussed later on.

So far we have concentrated rather on the derived mechanical units, But, with the addition to the MKS system of the ampere, kelvin, candela and mole to form the full SI system, the number of derived units is legion, and they cover every conceivable field of engineering, physics and science. Just a very few of them are shown below:—

Electricity and magnetism				
electric potential	volt	(V)	W/A	(Nm/sA)
resistance	ohm	(Ω)	V/A	(Nm/sA^2)
magnetic flux	weber	(Wb)	Vs	(Nm/A)
electric charge	coulomb	(C)	As	
inductance	henry	(H)	Wb/A	(Nm/A^2)
capacitance	farad	(F)	C/V	(A^{2}s^2/Nm)
magnetic field strength			V/m	(N/sA)
Thermal				
th. conductivity			W/m.K	
specific heat			J/kg.K	
Illumination				
luminance			cd/m^2	
luminous flux	lumen	(lm)	cd.sr	
illuminance	lux	(lx)	lm/m^2	
Physical chemistry				
molar volume			m^3/mol	
molar heat capacity			J/mol.K	

One thing is common to all: each is coherent, that is, they have a one-to-one relationship with each other and with the base units from which they are formed There are no conversion factors whatever, not even a π. This applies always so long as you keep exclusively to SI units, and particularly to the newton as the sole unit of force. This is of course an ideal requirement which can never be wholly met. Certain non-SI units are imposed on us by nature, for instance the minute, hour, day and year, and the degree, minute and second of angle, which from established usage can never be changed. Only when these non-SI units enter the calculations is care needed when converting.



radian (rad) steradian (sr)

FIG. 3

Supplementary Units

To complete the picture there are two further units which should be mentioned They are neither base nor derived units; indeed they are hardly units at all, since they have no dimension but are merely numerical ratios. They are called 'supplementary units' and are the units of plane angle and of solid angle.

The radian is defined as the angle subtended at the centre of a circle by an arc equal in length to the radius. The steradian is the solid angle subtended at the centre of a sphere by an area on the surface equal to the square of the radius. Both form derived units on their own account, such as angular velocity (rad/s) and angular acceleration (rad/s^2). The steradian is used in units concerning illumination and radiation problems. These units of angle must always be used in preference to degrees in calculations in SI units because of their coherence. For example, a torque of one newton-metre operating through an angle of one radian does one joule of work, and if it does it in one second it works at an average rate of one watt.

Unit of Pressure and Stress

The unit of pressure is perhaps one of the commonest units in everyday use. It is a force per unit area and so, in SI terms, is measured in N/m^2. Stress in materials is an identical concept to pressure (though usually much larger) in that it too is a force per unit area and so, in SI terms, is also measured in N/m^2.

Now the weight of an apple spread over a square metre is a very small pressure indeed, and in this respect the SI unit of pressure is impractically small for most engineering purposes. Here the metric system comes to our rescue, because we can talk of kN/m^2 or even MN/m^2 without loss of clearness. As one psi is equivalent to 6930 N/m^2 (very roughly 7 kN/m^2), for rough estimating purposes it is easy to go in the mind from psi to kN/m^2 simply by multiplying by 7. This covers most steam, water and hydraulic pressures. For stresses in materials and elasticity calculations the MN/m^2 is probably a more convenient unit.

In France a name, the 'pascal' has been given to the SI unit of 'newtons per square metre' and is abbreviated to 'Pa'. The pascal is now officially recognized by British Standards as the name for the derived unit of pressure and stress, N/m^2. In this country powerful interests, mainly the steel industry, would prefer to use the 'bar'; its value is 10^5 N/m^2 or 10^5 Pa, but it must be emphasised that it is not an SI unit; that is to say, it is not coherant and does not have a one-to-one relationship with other SI units. Even if used for measurements, it must be converted into pascals (or N/m^2) in calculations. The steel men find that the bar is numerically very nearly the same as the kgf/cm^2 which they have been using before SI. In fact they would prefer to use that abortion the hectobar which is nearly equal to 1 kgf/mm^2 and which they can visualize better. This is the very worst of reasons for taking such a retrograde step, as it completely undermines the whole coherent concept of the SI system. I hope that they won't succeed.

Units of Energy and Power

Work or energy is measured in newton-metres or joules, and power (that is, rate of doing work) is measured exclusively in watts in the SI system; this means power in any form whatever. There is no place for such horrors as horsepower. The mechanical output from a turbine or engine or electric motor is to be measured now in watts (or kilowatts or megawatts), never in horsepower. In the case of a motor its efficiency is immediately apparent as the ratio of the mechanical kilowatts output to the electrical kilowatts input.

The unit of power—the horsepower—was based on the assumption that a horse can travel at 2½ miles per hour for eight hours a day, performing the equivalent of pulling a load of 150 lb out of a shaft by means of a rope. Was there ever a more non-standard British unit!

Heat is also a form of energy, and in transfering heat from one place to another work is done at a given rate. This represents power and is, in SI units, also rated in kilowatts. To distinguish it from the mechanical or electrical kilowatts it is often expressed as 'kilowatts (thermal)'. But kilowatts it is. Instead of rating, say, a refrigerator or air-conditioning plant as so many million BTU/hr, it is rated simply in 'kilowatts (thermal)' between stated temperatures. For such a plant, the coefficient of performance is immediately apparent as the ratio of kilowatts (thermal) output to kilowatts (mechanical) input, without any horrible conversion calculations.

For boilers and all types of heat engine, fuel consumption is so much chemical energy used in a given time (kilowatts (chemical)); heat output or input is in kilowatts (thermal), and shaft output in kilowatts (mechanical). All can be directly compared for efficiency, and indeed the Carnot cycle can be simply interpreted.

On the subject of heat, for thermodynamic work the absolute scale must be used, previously called the 'degree kelvin' (or °K). Recently however it has been decided internationally to drop the word 'degree' and just call the absolute unit the 'kelvin' (K). For day-to-day practical purposes the degree Celsius (°C) may still be used (note that the 'degree' is still retained). There is now no distinction between the units for temperature difference and for temperature itself. Although the kelvin and celsius temperature intervals are the same, their numerical values differ; the former is referred to as the 'thermodynamic temperature' and the latter as the 'celsius temperature'.

Specific heat is no longer related to water nor is it now given in calories per unit mass. It is given in SI units, joules per kilogramme per kelvin (being the energy required to raise 1 kilogramme of that substance through one kelvin of temperature under defined conditions). We no longer have to bring in that difficult concept the 'mechanical equivalent of heat'. It is taken care of in the specific heat unit J/kg.K itself.

Conventions

It is necessary to have certain disciplines and conventions in the actual use of SI units to ensure that they are kept as simple as they should be.

The accepted prefixes covering the range 10^{12} down to 10^{-18} have already been listed. All these powers are themselves multiples of three except the smallest ones (hecto-, deca-, deci- and centi-). Because of the width of this range, it is hoped internationally to concentrate solely on the prefixes representing powers of three and to let the others (hecto-, deca-, deci- and centi-) die a natural death. This will not be achieved commercially, where your wife will probably continue to buy her ribbon by the centimetre and you will certainly buy your short drinks by the centilitre: but for engineering purposes the third-power scheme will probably be sufficient, for example, drawings will normally be dimensioned in millimetres. There may however be a few lone survivors such as the decibel.

Another important discipline is that multipiple prefixes should always be in the numerator, never the denominator. This makes it clear that they apply to the whole unit. Thus:—

$$\underset{\text{(deprecated)}}{\text{N/mm}^2} = \underset{\text{(multiple of an SI unit)}}{\text{MN/m}^2} \qquad \text{(also = MPa)}$$

Another is the rather obvious convention that powers, like the mm^2 here, apply to the whole expression. Thus $\text{km}^2 = (\text{km})^2$ and not $\text{k}(\text{m})^2$ and so represents a million, not a thousand, square metres.

The rule for the names and abbreviations of units is quite simple. If the unit is named after a person, the abbreviation is written with a capital letter, otherwise a small (lower case) letter is used. Sometimes there must be two letters used to avoid confusion.

Names

V = volt
A = ampere
W = watt
J = joule
N = newton
K = kelvin
H = henry
Hz = hertz
B = bel
Wb = weber
F = farad
etc.

Others

m = metre
g = gramme
l = *litre
s = second
cd = candela
lm = lumen
lx = lux
rad = radian
etc.

*The litre is not strictly an SI unit being 1 dm^3 (non-coherent)

Note however that, when a named unit is written *in full*, the name is always written with a small initial letter even though it is the name of a person: thus volt, not Volt; newton, not Newton.

The letter 's' must never be used for plurals in abbreviations, as it would be confused with 's' for second: thus grammes is always 'g', not 'gs' or 'grs'. Full-stops are never used for abbreviations except as a sign of multiplication if desired, but not strictly necessary.

You must not use two prefixes to the same unit. You do not speak of a 'millimicrosecond' (mμs) but of a straight 'nanosecond' (ns). When deciding what prefix to use, a good rule is to arrange things so that you normally have a whole number of not more than three figures; thus, write 20 km rather than 20,000 m, or 65 mm rather than 0·065 m. Although this is a good general rule, it must be used with common sense. For example, in a long calculation the magnitude of a quantity may range from very large to very small, and it is obviously better to keep to one unit—preferably the main unprefixed unit—throughout. When doing this, to avoid having very long numbers or having a large number of zeros after the decimal point, you can always use a power of 10 as a factor. For example, if you decide to stick to metres throughout, 20,000 metres can be written as 20×10^3 m, or 0·000035 watts can be written as 35×10^{-6}W.

Conclusion

The adoption of SI units means far more than just changing to a decimal system. The SI is a coherent system of units where each has a one-to-one ratio to those from which it is formed. It is intended that these units and these units only shall be used in calculations.

Any of the few remaining non-coherent units which are imposed by nature and are unalterable, such as the hour and day or the degree of angle, or those in wide use, such as the litre, or adopted by certain industries, such as the bar, must first be put into SI before being used in calculations.

The SI system vastly simplifies the arithmetic, removes that huge array of conversion factors which plague the life of every engineer and in using the newton exclusively as the unit of force puts, once and for all, the *g* firmly in its place.