Units of measurement

Why standardisation is important

- You have 5 minutes with the person next to you to discuss why you think standardisation is important in engineering

- Submit your answers to the padlet

Imperial vs Metric

Metric	Imperial
• Based on **7 base units**	• Uses inches, feet, pounds, gallons
• Uses a decimal system (*10) making it easier to scale	• **No consistent pattern** (12in = 1ft, 3ft = 1 yard, 16 oz = 1lb)
• Consistent, logical and used **worldwide**	• Still used in some industries and countries
• Required in engineering and science	• Prone to mistakes when converting

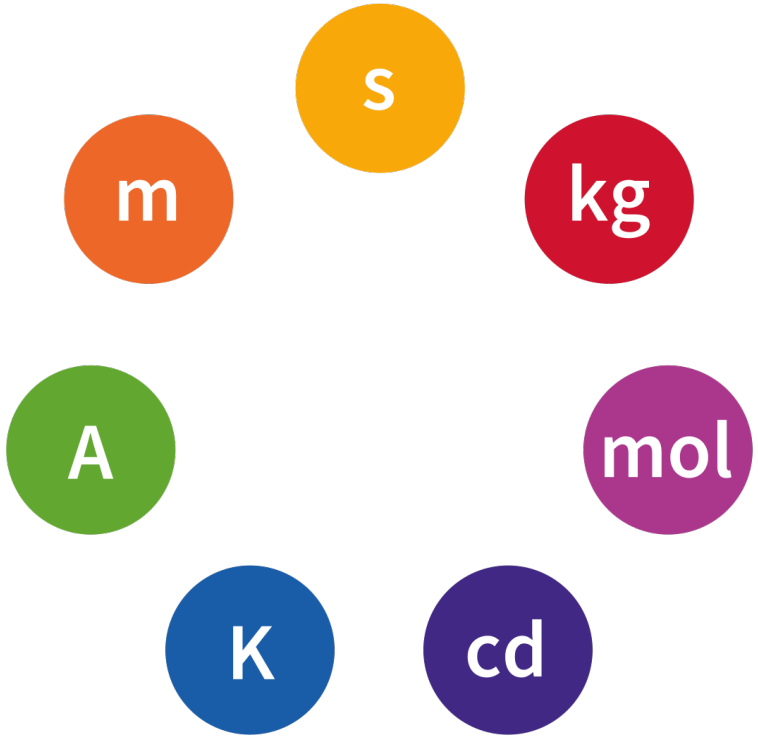
Système International d'Unités

- The modern metric system is entirely based around SI units
- These units were internationally agreed in 1960 at the **General Conference on Weights and Measures (CGPM)** however they had been developed since the 1800s
- They provide a single standard set of units that all humans can use worldwide
- They built it around 7 base units

Members of the 10th CGPM which developed early steps towards CGPM

Base SI Units

- There are 7 “base” units in engineering and science
- All other units are built from these base units
- They are the “building blocks” of derived units



Base SI Units - Time

- Time is measured in **seconds**
- These have the units **s**
- The duration of 9,192,631,770 oscillations of radiation from the caesium-133 atom.
- Used to be based on $1/86400$ of a mean solar day but due to uneven rotation of the earth it was changed to be something more predictable

Base SI Units - Mass

- Time is measured in **kilograms**
- These have the units **kg**
- Based on the Planck constant “h” which is $6.62607015 * 10^{-34}$
- The Planck constant (h) is just a really, really tiny number that tells us how much energy is in one “packet” of light (a photon) for each wave of it.

Base SI Units – Amount of Substance

- Time is measured in **mole**
- These have the units **mol**
- Contains exactly $6.02214076 * 10^{23}$ entities (Avogadro's number)
- As atoms are far too small to logically count scientists measured gas values like volumes, masses and electric charges to determine how many atoms it has and thus how many "moles"

Base SI Units – Luminous Intensity

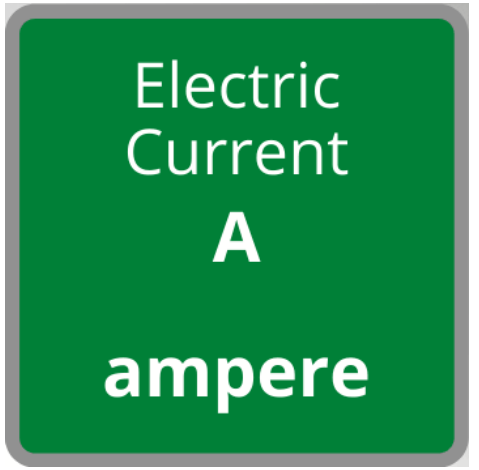
- Time is measured in **candela**
- These have the units **cd**
- Luminous intensity in each direction of a source emitting monochromatic radiation at 540 THz with radiant intensity 1/683 W
- The definition basically just means the measurement of a single colour green light (540THz) in a single direction at an intensity of 1/683 watts.

Base SI Units – Thermodynamic Temperature

- Time is measured in **kelvin**
- These have the units **K**
- Defined via the Boltzmann constant $k = 1.380649 * 10^{-23}$ J/K
- The unit size for K and for °C is the same. The only difference is K starts at -273.15°C so T(K)=T(°C)+273.15
- We use it as it is always positive which makes equations easier

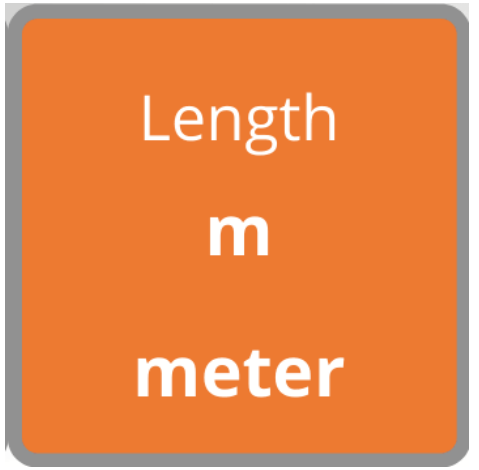
Base SI Units – Electric Current

- Time is measured in **ampere**
- These have the units **A**
- Defined via the elementary charge $e = 1.602176634 * 10^{-19}$
- The elementary charge (symbol e) is the smallest unit of electric charge that exists in nature.
- (1 proton = +e) (1 electron = -e)



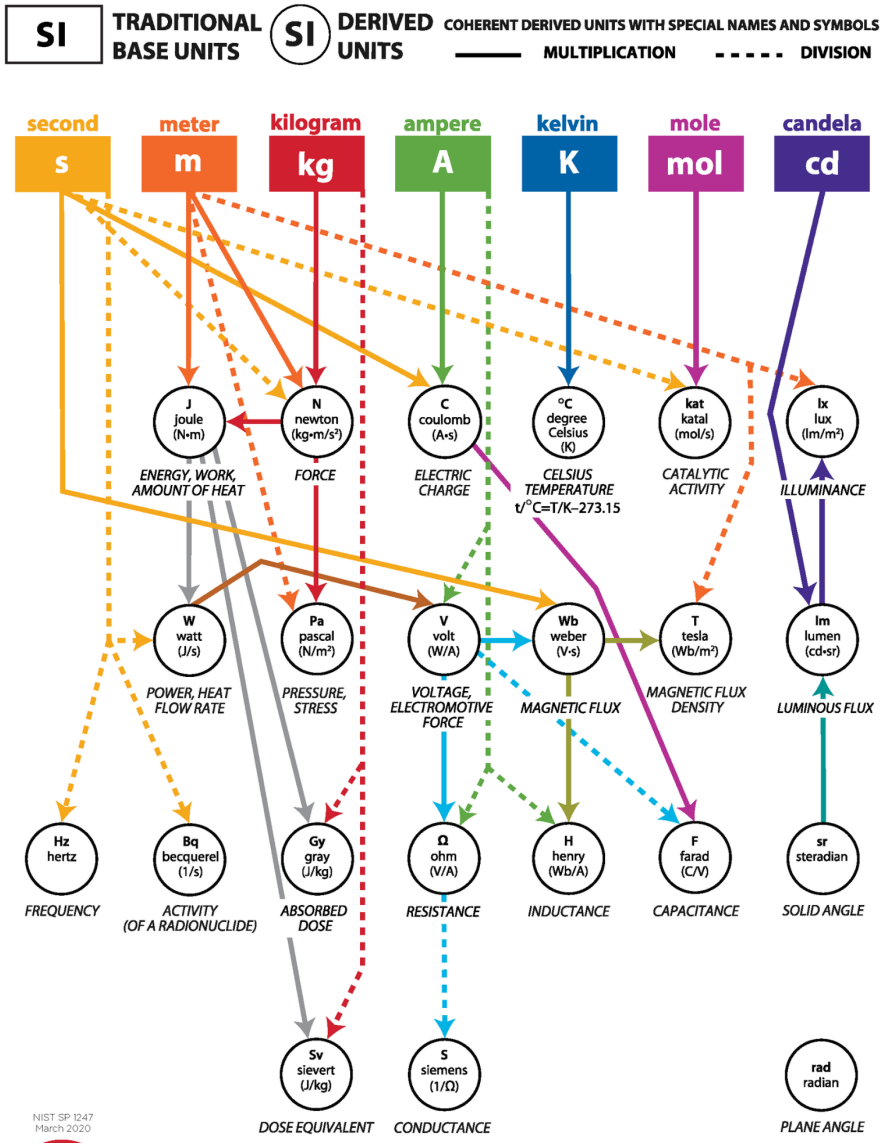
Base SI Units – Length

- Time is measured in **metres**
- These have the units **m**
- Distance light travels in vacuum in $\frac{1}{299,792,458}$ of a second
- This value is based on the speed of light as c=299,792,458m/s



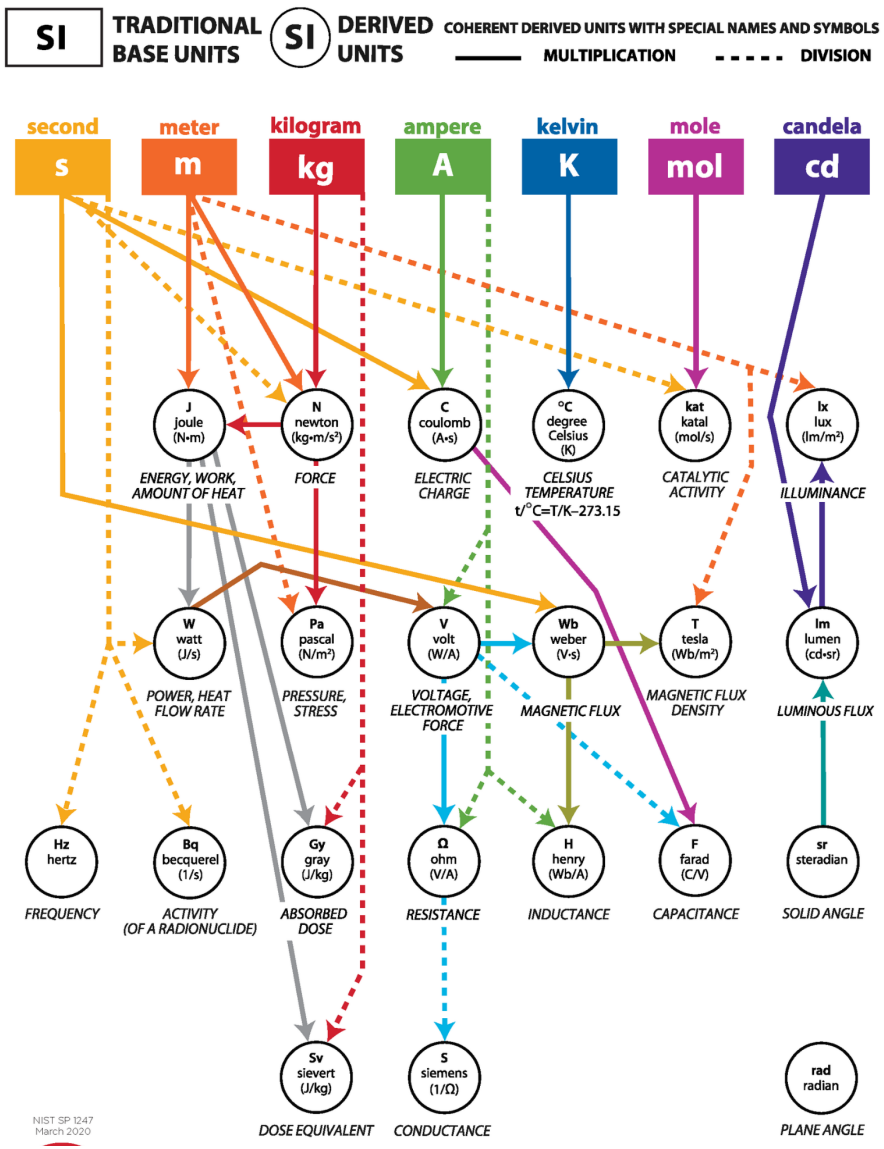
Derived SI Units

- A derived unit measures more complex values
- They are “constructed” out of the base SI Units
- They can always be written in their “base form”



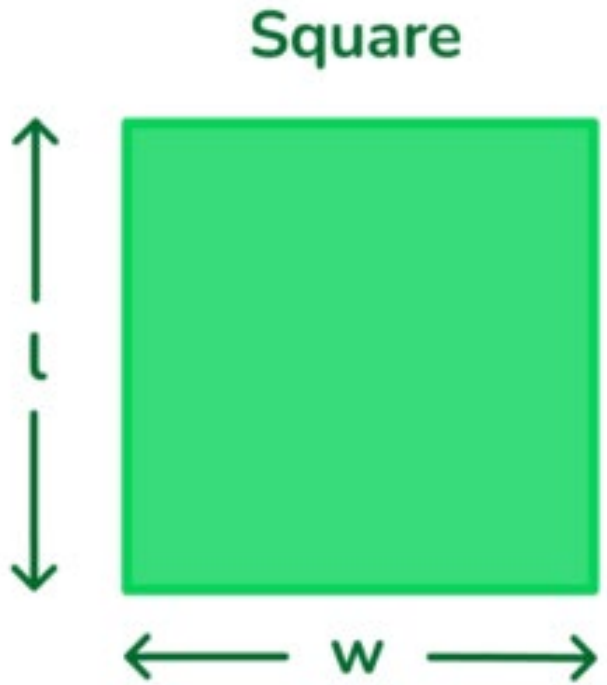
Derived SI Units

- A derived unit measures more complex values
- They are “constructed” out of the base SI Units
- They can always be written in their “base form”
- They always contain at least two base units



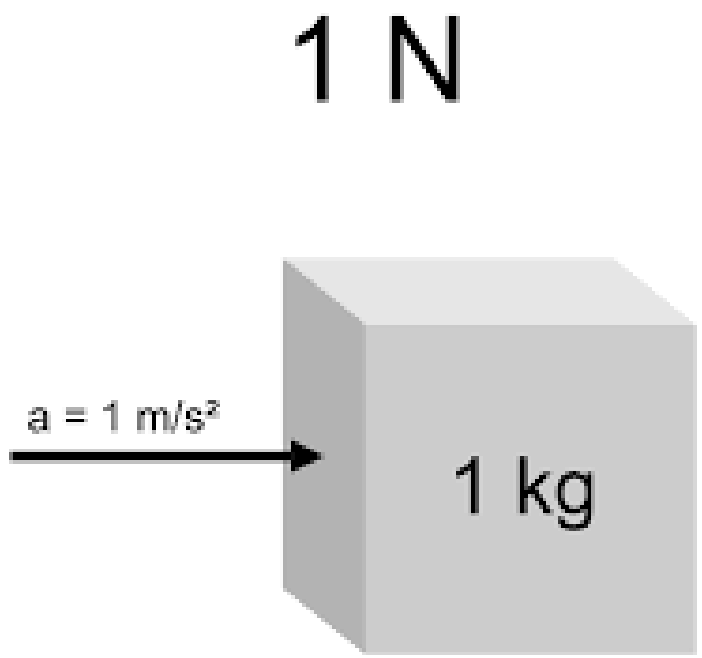
Derived SI Units - Area

- One of the simplest derived units is **area**
- Area has the symbol $\boldsymbol{m^2}$
- This means it is made from the base units $\boldsymbol{m} * \boldsymbol{m}$ which is **length * length**



Derived SI Units - Force

- Another derived unit is **newtons**
- Force has the symbol **N**
- However, in base units Force is defined as $\boldsymbol{kg * m/s^2}$



Unit multiples and submultiples

- Engineering and science often deals with **very large or very small numbers**
- SI units use **prefixes** to make numbers easier to read and work with
- All these prefixes are **powers of 10** which makes them easy to use
- These prefixes come from across Europe including Latin, Greek and modern made-up words

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

All prefixes

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

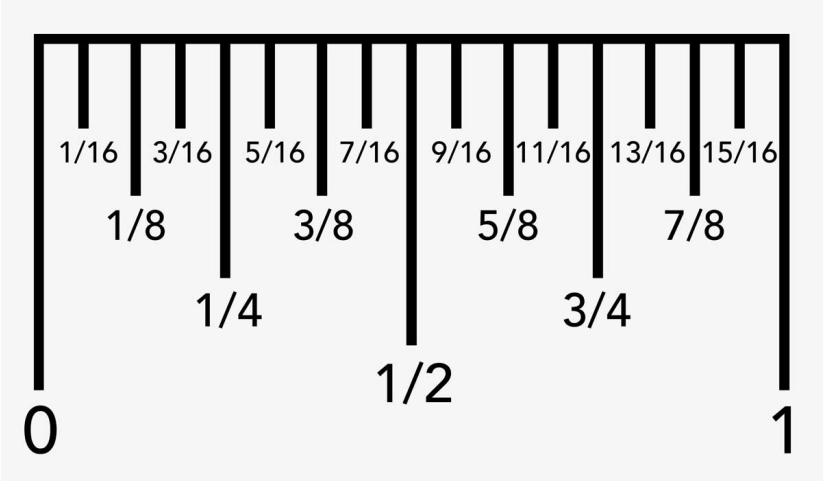
So why were imperial units used?

- Imperial units were used in the past (and in the present) because they are **easily dividable**
- For example, in the imperial system **1 foot = 12 inches**
- The number 12 is easily divided into:
  - 2 (6 inches = half a foot)
  - 3 (4 inches = a third of a foot)
  - 4 (3 inches = a quarter of a foot)
  - 6 (2 inches = a sixth of a foot)
- This made it easy to divide building materials by **eye and hand** without calculators and rulers

Length	Mass	Capacity
1 yard = 3 feet 1 foot = 12 inches 1 mile = 1760 yards	1 pound = 16 ounces 1 stone = 14 pounds	1 gallon = 8 pints

Imperial units - Length

- In imperial measurements length is measured in inches, feet, yards and miles
- 12 inches (“) = 1 foot (‘)
- 3 feet (‘) = 1 yard (yd)
- 1760 yards (yd) = 1 mile (mi)
- 1 mile = 1760 yards = 5280 feet = 63360 inches
- 1 foot = 0.3048 metres



Imperial units – Mass

- Ounces are awkward as it can mean two different values, either mass or volume depending on what you're talking about
- We use the mass version when weighing something
- 16 ounces (oz) = 1 pound (lb)
- 1 ounce ≈ 28.35 grams

Imperial units – Volume

- Ounces are awkward as it can mean two different values, either mass or volume depending on what you're talking about
- For liquids we use fluid ounces
- 20 ounces (oz) = 1 pint (pt)
- 8 pints (pt) = 1 gallon (gal)
- 1 ounce ≈ 28.41 millilitres

Note this is the UK conversion, America does it different