# Units of measurement

# 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 |

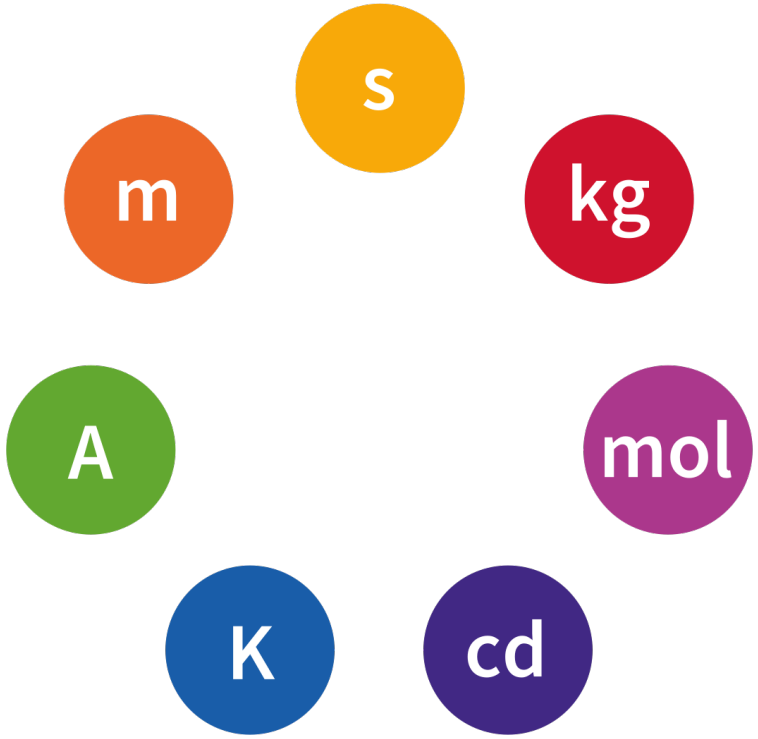
# Système International d'Unités

- 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

- Mass 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

- Substance 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

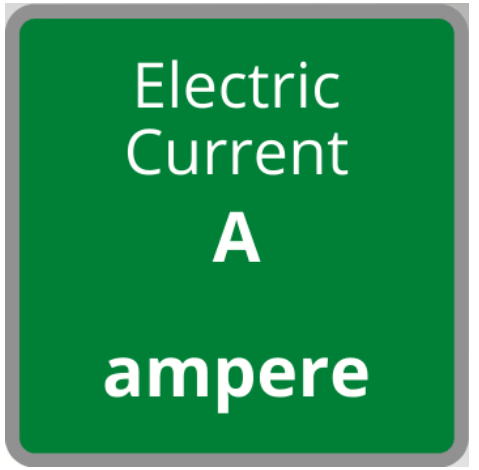
- Luminous Intensity is measured in **candela**
- These have the units **cd**
- Luminous intensity in each direction of a source emitting monochromatic radiation at 540 THz with radiant intensity 1/683 W
- The definition basically just means the measurement of a single colour green light (540THz) in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

# Base SI Units – Thermodynamic Temperature

- Thermodynamic Temperature 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

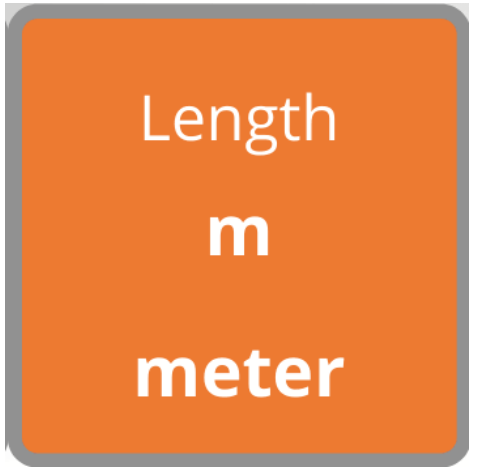
# Base SI Units – Electric Current

- Electric Current 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)



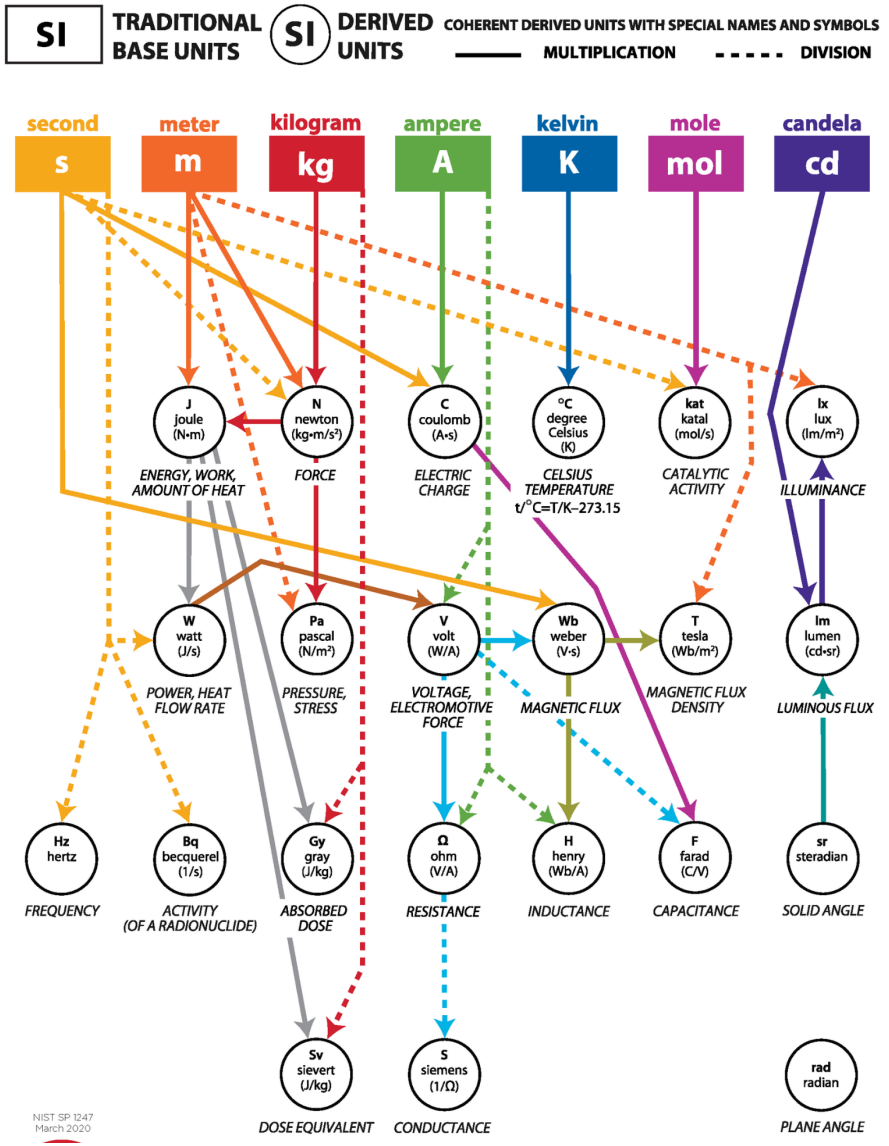
# Base SI Units – Length

- Length 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



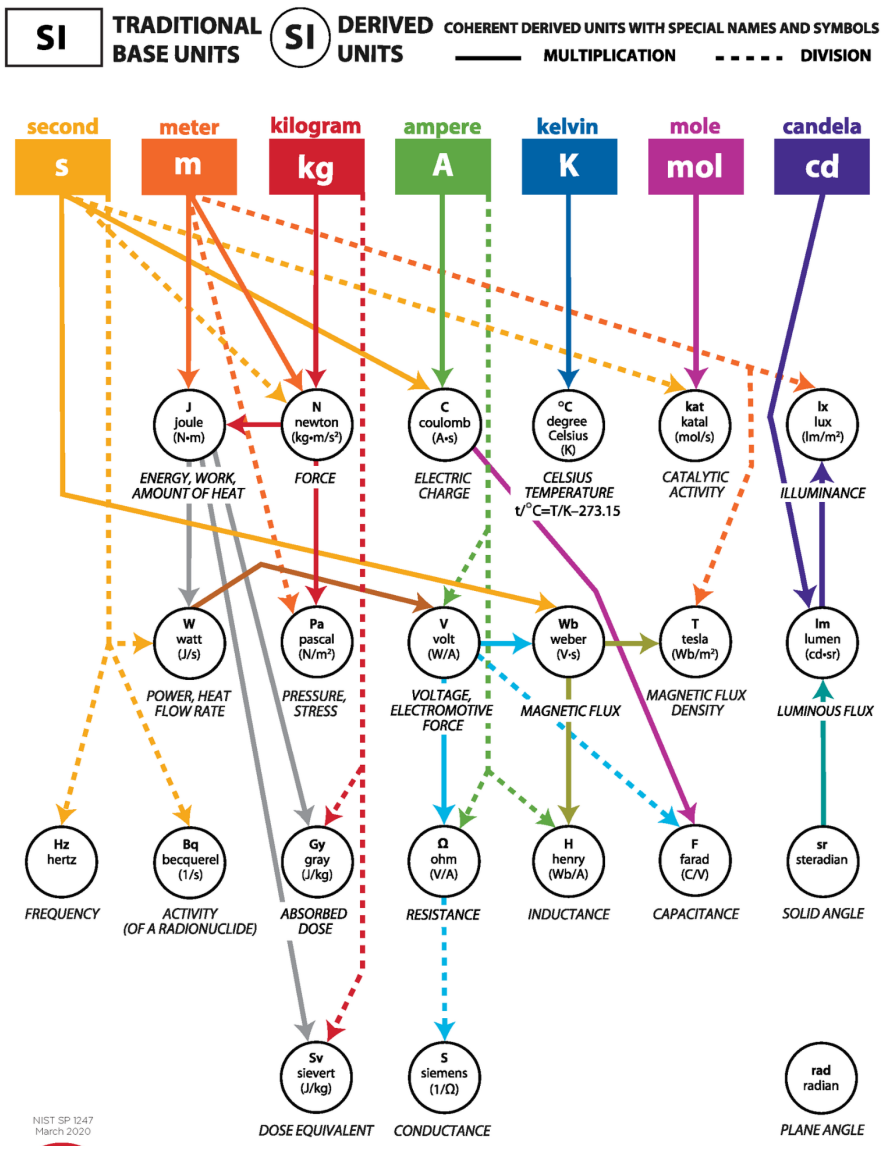
# Derived SI Units

- 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”



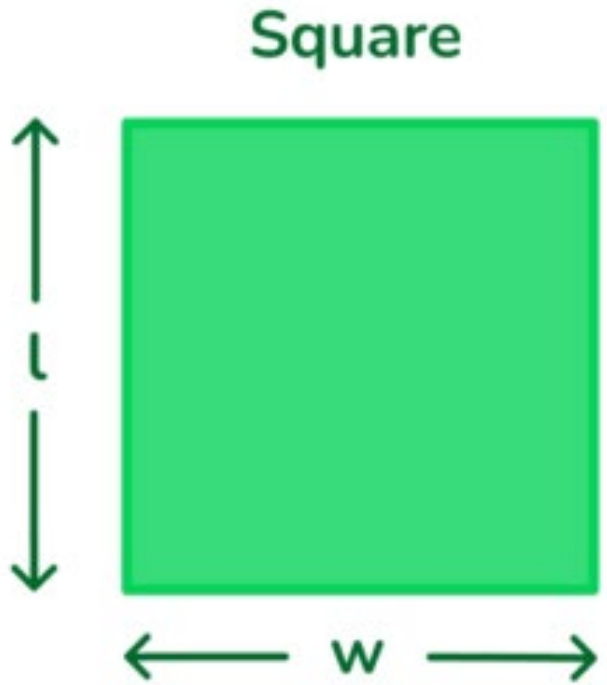
# Derived SI Units

- 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



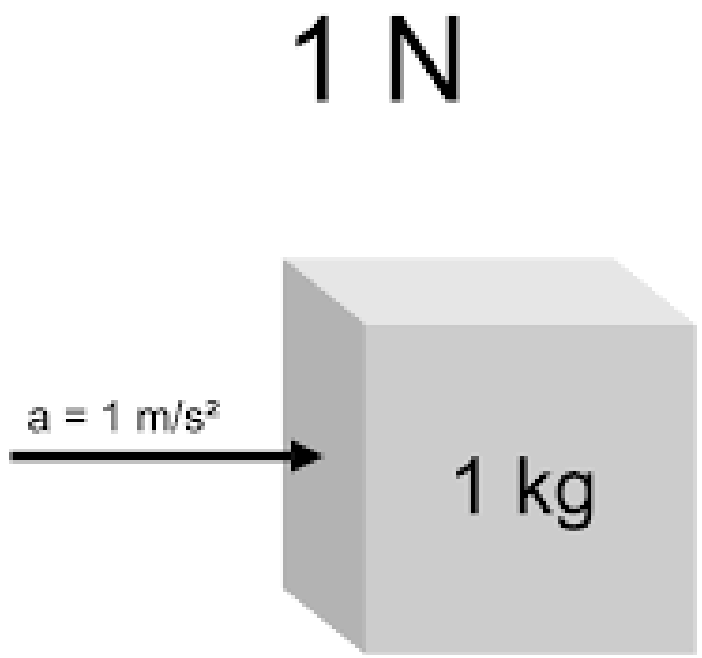
# Derived SI Units - Area

- 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 |

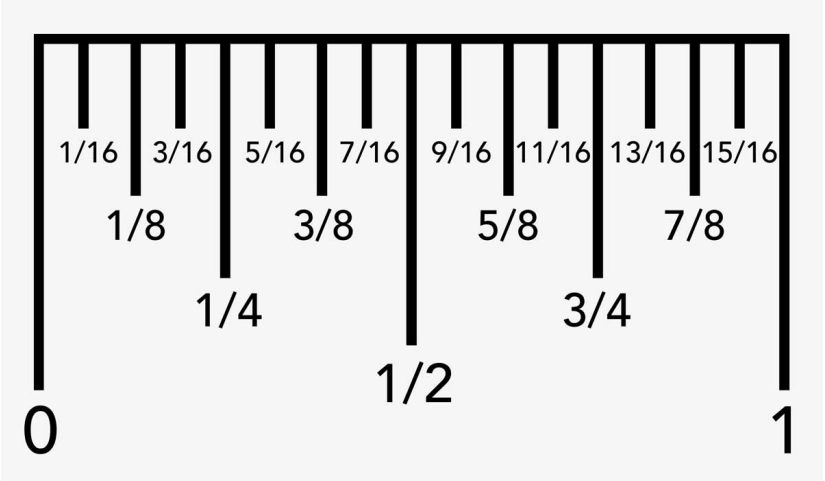
# So why were imperial units used?

- 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<br>1 foot = 12 inches<br>1 mile = 1760 yards | 1 pound = 16 ounces<br>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*