- **Derived units** (derived from the base units)
  - **Volume (V)** → 1 m^3 = (1 m) × (1 m) × (1 m)

1 mL = 1 cm^3 = (1 cm)×(1 cm)×(1 cm) = (10^{-2} m)×(10^{-2} m)×(10^{-2} m) = (10^{-2}×10^{-2}×10^{-2}) m^3 = 10^{-6} m^3

1 L = 1 dm^3 = 10^{-3} m^3 **1 mL= 10^{-3} L**

  - **Density (d)** → mass (m) per unit volume (V) → ($d = m/V$)

unit of d = (1 kg)/(1 m^3) = 1 kg/m^3

  - **Velocity (v)** → distance (l) per unit time (t) → ($v = l/t$)

unit of v = (1 m)/(1 s) = 1 m/s

- **Extensive properties** – depend on sample size (mass, volume, length, ...)
- **Intensive properties** – independent of sample size (density, temperature, color, ...)

Example:

What is the density of an alloy in g/cm^3, if **55 g** of it displace **9.1 mL** of water?

$d = m/V$ = (55 g)/(9.1 mL) = 6.0 g/mL = 6.0 g/cm^3

Example:

- Convert the density of gold, **19.3 g/cm^3**, to **kg/m^3**.

⇒ need to convert both the numerator and denominator g → kg **and** cm^3 → m^3

1 kg = 10^3 g

1 cm = 10^{-2} m ⇒ 1 cm^3 = $(10^{-2})^3$ m^3 = 10^{-6} m^3

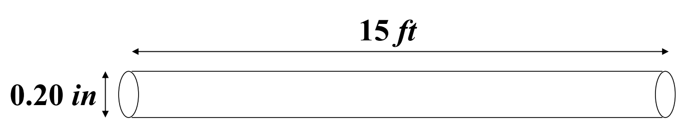
$$d = 19.3\frac{g}{cm^3}\times\left(\frac{1\,kg}{10^3\,g}\right)\times\left(\frac{1\,cm^3}{10^{-6}\,m^3}\right) = 19.3\times10^3\,\frac{kg}{m^3}$$

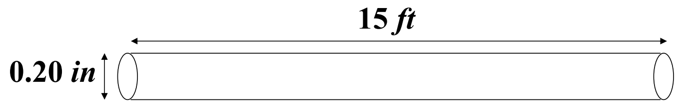
Example:

What is the mass in ***kg*** of a **15 *ft*** wire made of an alloy with ***d* = 6.0 g/cm^3** if the diameter of the wire is **0.20 *in***?

Plan:

Diameter→radius (cm)→cross-section area (cm^2)
Length (cm) × cross-section area → volume (cm^3)
Volume & density → mass (g) → mass (kg)





Radius $\rightarrow r = 0.20\ in / 2 = 0.10\ in$

$$r = 0.10\ \cancel{in} \times \left(\frac{2.54\ cm}{1\ \cancel{in}}\right) = 0.254\ cm$$

$$A = \pi r^2 = 3.14 \times (0.254\ cm)^2 = 0.203\ cm^2$$

$$l = 15\ \cancel{ft} \times \left(\frac{12\ \cancel{in}}{1\ \cancel{ft}}\right) \times \left(\frac{2.54\ cm}{1\ \cancel{in}}\right) = 457\ cm$$

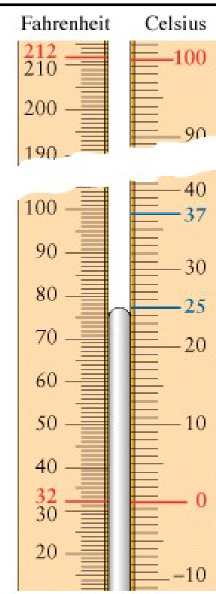
$$V = l \times A = 457\ cm \times 0.203\ cm^2 = 92.7\ cm^3$$

$$m = 92.7\ \cancel{cm^3} \times \left(\frac{6.0\ \cancel{g}}{1\ \cancel{cm^3}}\right) \times \left(\frac{1\ kg}{1000\ \cancel{g}}\right) = 0.56\ kg$$

- **Temperature (*T*)** – a measure of how hot or cold an object is relative to other objects
  - *T* reflects the thermal energy of the object
  - *T* is an intensive property
- **Heat** – the flow of thermal energy between objects
  - Heat flows from objects with higher *T* to objects with lower *T*
  - Heat is an extensive property
  - Heat and temperature are different
- Thermometers
  - Used to measure *T*

- The **Celsius** scale
  - 0ºC → freezing point of water
  - 100ºC → boiling point of water
- The **Fahrenheit** scale
  - 0ºF → freezing point of salt/water mixture
  - 100ºF → body temperature
  - water freezes at 32ºF and boils at 212ºF

⇒100 Celsius degrees ↔ 180 Fahrenheit degrees



$$\left(\frac{180°\ F}{100°\ C}\right) = \left(\frac{9°\ F}{5°\ C}\right)$$

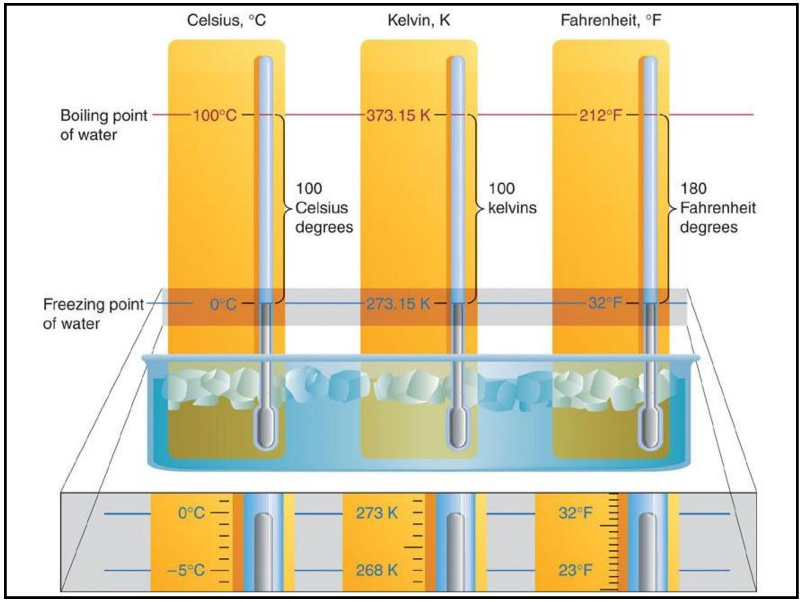
$$T°F = \left(\frac{9°\ F}{5°\ C}\right) T°C + 32°\ F$$

$$T°C = \left(\frac{5°\ C}{9°\ F}\right)(T°F - 32°\ F)$$

- The **Kelvin** scale - absolute temperature scale
  - 0 K → lowest possible temperature
  - 0 K = -273.15°C
  - same size of degree unit as Celsius

⇒water freezes at 273.15 K and boils at 373.15 K

- $\boldsymbol{T\,\text{K} = T\text{°C} + 273.15}$
- $\boldsymbol{T\text{°C} = T\,\text{K} - 273.15}$



Example:

- Convert -40°F in °C and K.
- $\boldsymbol{T\text{°C} = (5\text{°C}/9\text{°F}) \times [-40\text{°F} - 32\text{°F}] =}$

  $\boldsymbol{= (5/9) \times (-72)\text{°C} = -40\text{°C}}$
- $\boldsymbol{T\,\text{K} = -40\text{°C} + 273.15 = 233\,\text{K}}$